University of Antwerp

Digital Twin Design

Drivetrain workflow explained

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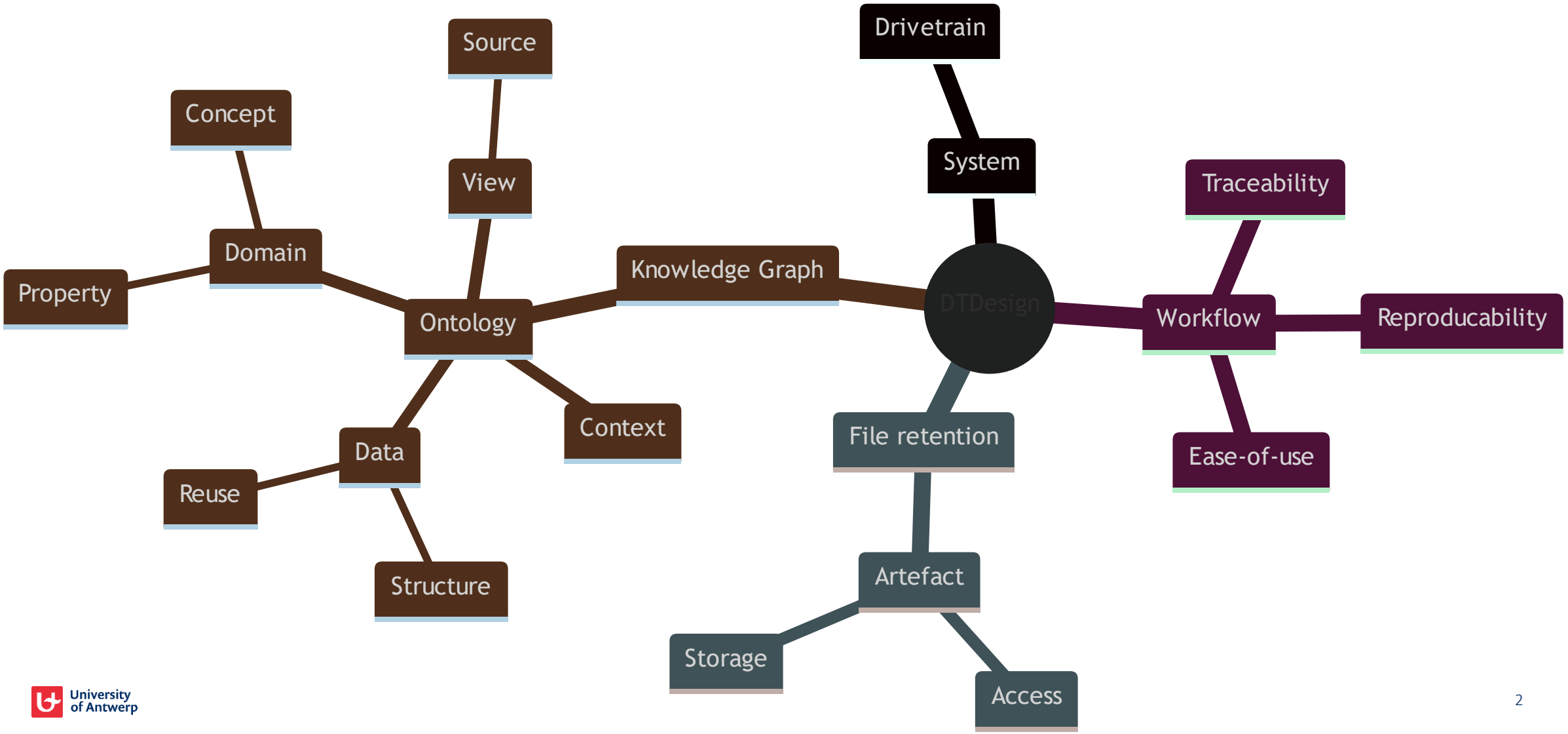
Model Based Systems Engineering

2023-09-01

What is Digital Twin Design about?



What are we using as the use case?

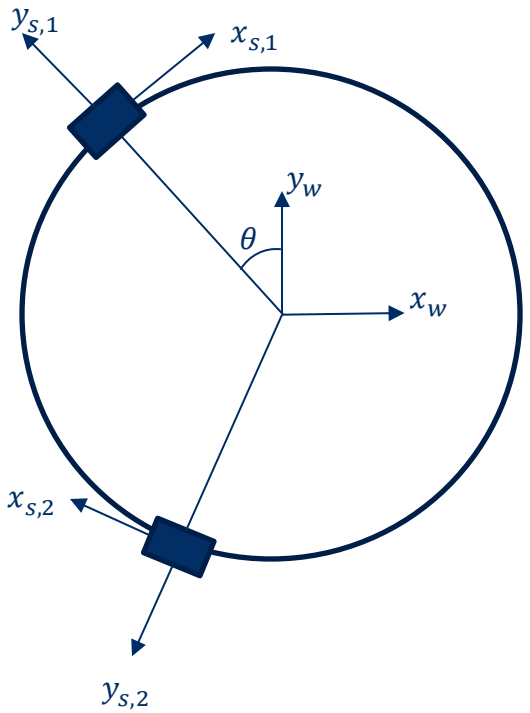
Context is important

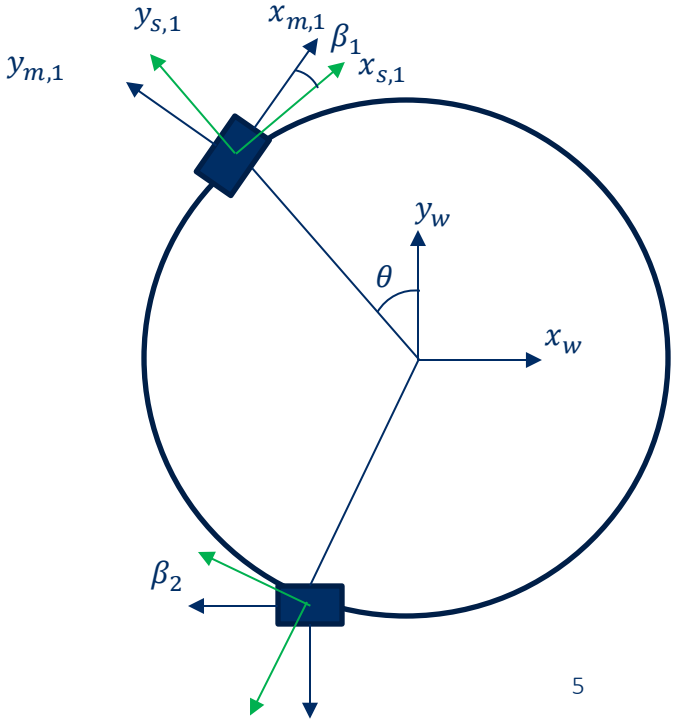
while managing data/information/knowledge

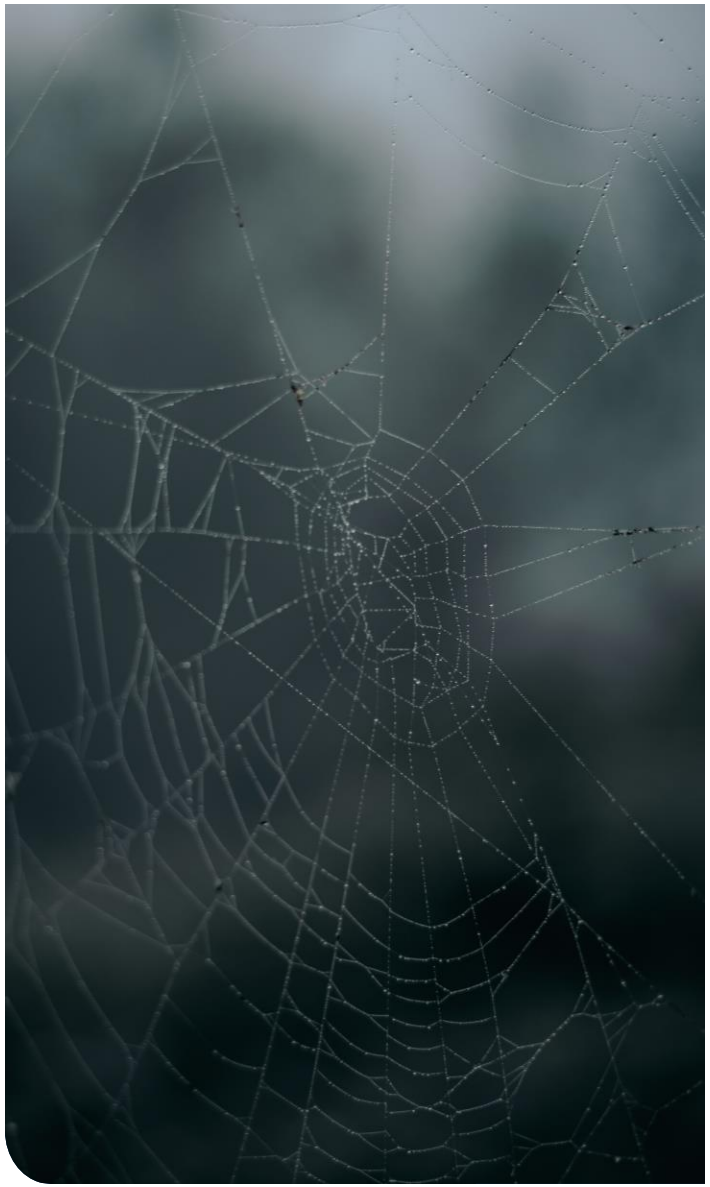
because it allows for more reproducible results

```
C:.
├─2D corrected x and y sensors
│  └─codegen
│      └─mex
│          └─kinematic_estimator_2D_original
│              └─interface
├─2D lateral only cross coupling
│  └─codegen
│      └─mex
│          ├─kinematic_estimator_2D_original
│          │  └─interface
│          └─kinematic_estimator_2D_residual
│              └─interface
├─2D only lateral acceleration
│  └─codegen
│      └─mex
│          └─kinematic_estimator_2D_residual
│              └─interface
├─2D only lateral acceleration updated
│  └─codegen
│      └─mex
│          ├─kinematic_estimator_2D_original
│          │  └─interface
│          └─kinematic_estimator_2D_residual
│              ├─html
│              └─interface
└─codegen
    └─mex
        ├─kinematic_estimator_2D
        │  └─interface
        └─kinematic_estimator_2D_residual
```

We have a problem...

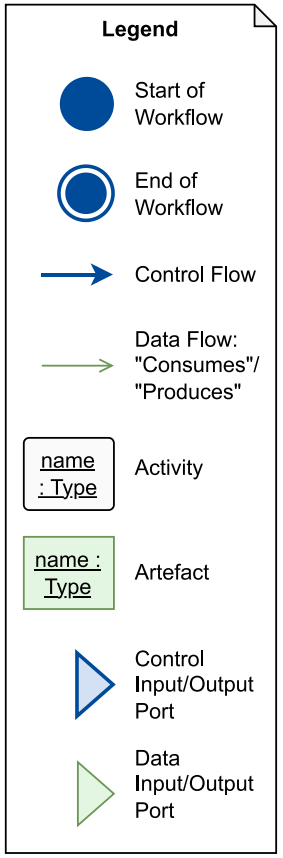


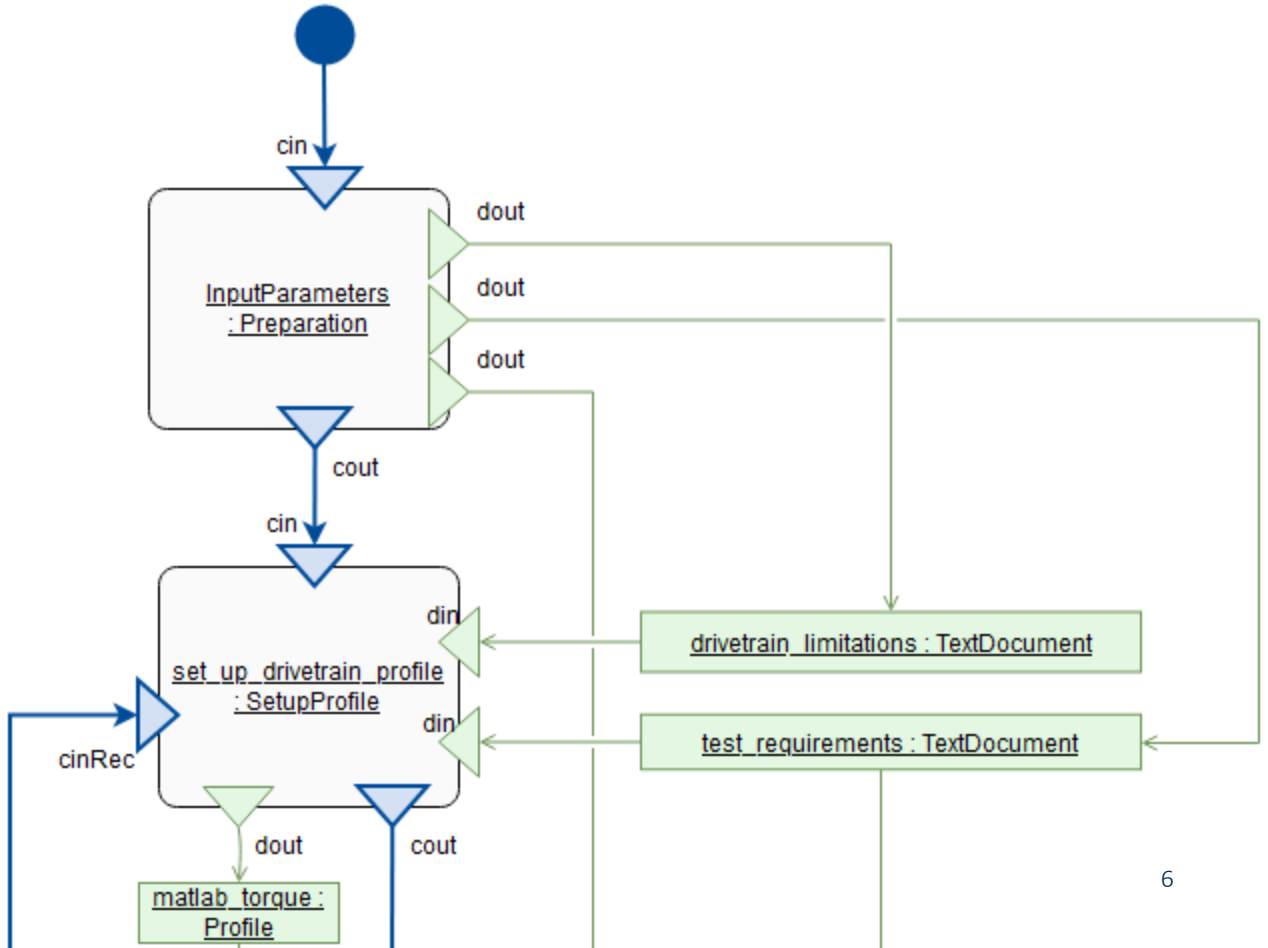




A wild solution appears!

Virtual Knowledge Graph?





Answering the 3 ‘W’!

Why was an experiment performed?

What changed between design iterations?

~~**W**~~ **How** did a model perform?

Queries

Visual

A few tools

End user facing

- Drawio
- Graph Exploring Tool
- Workflow Enactment Engine

Backend

- Fuseki
- SpEndpoint
- Backend :)

Transient

- OML Tooling

+ A bunch more

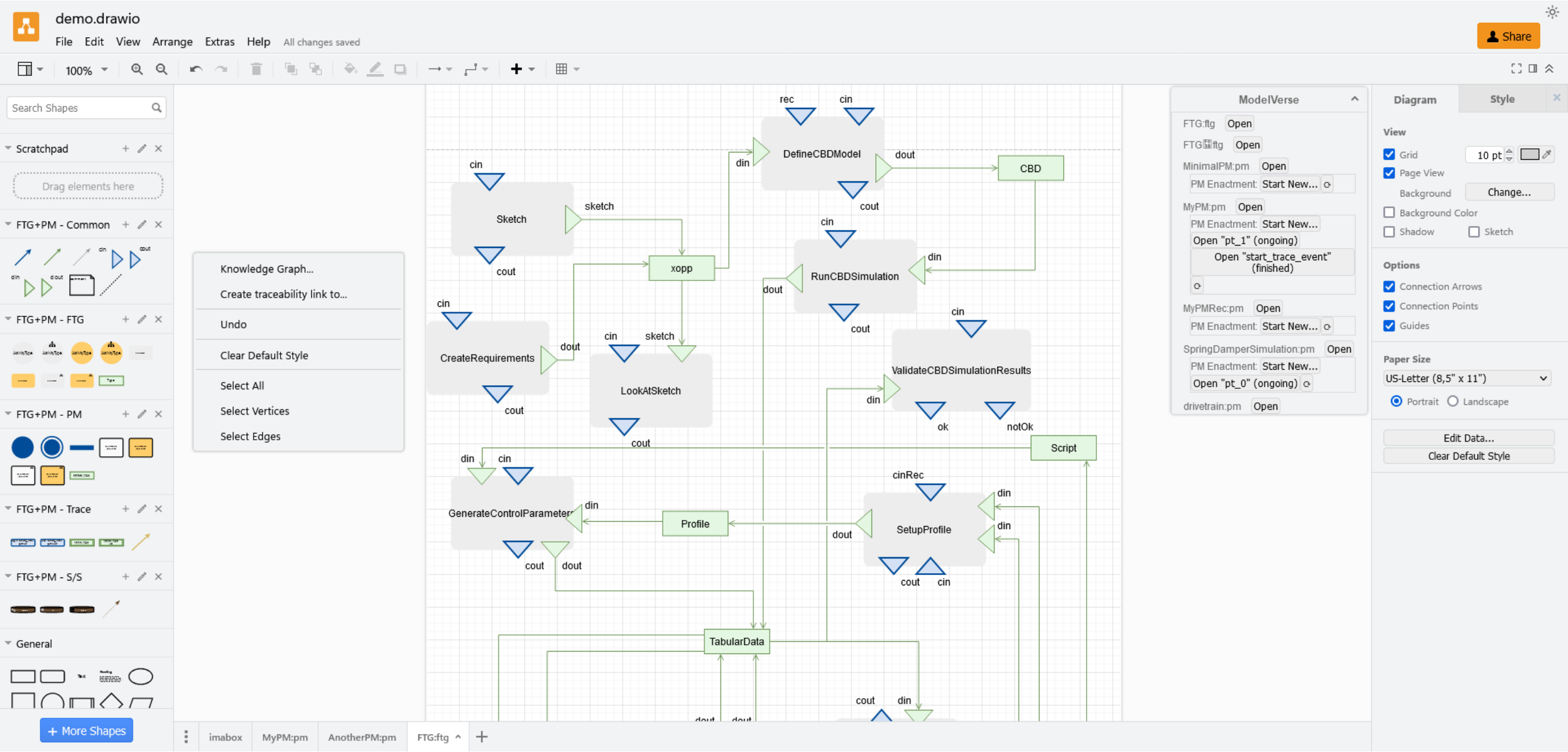
Let’s do a quick demo

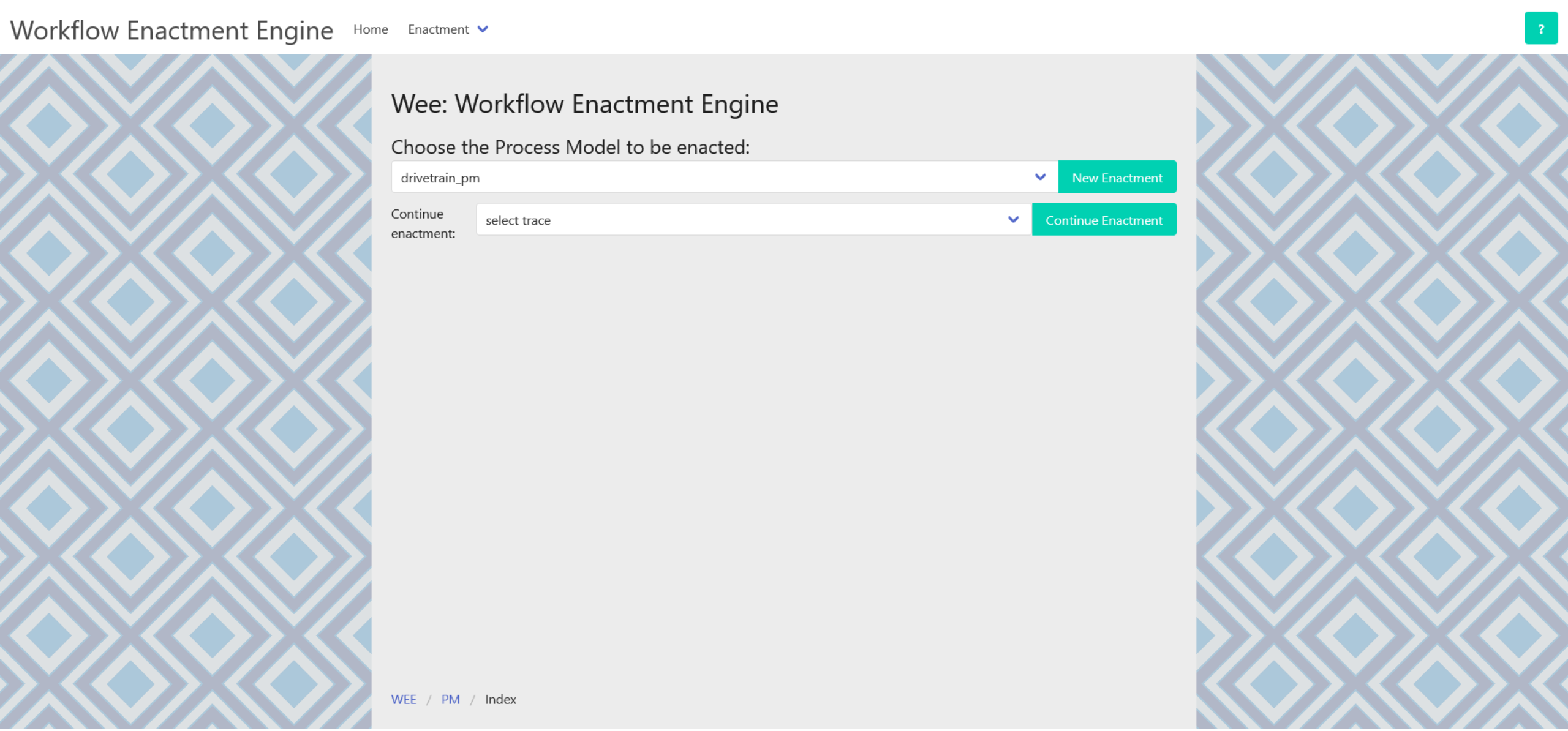
Modelling Environment

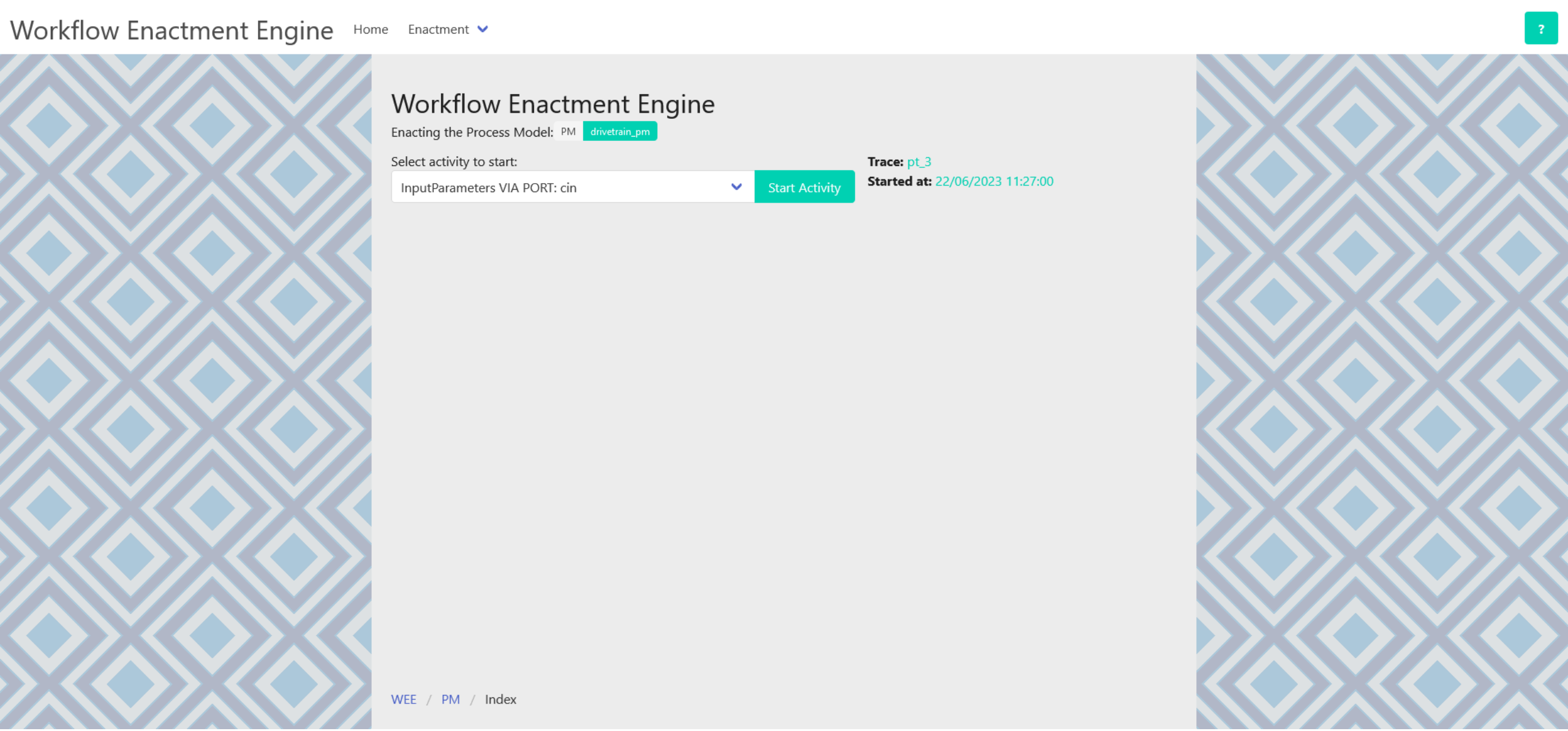
Workflow Enactment Engine

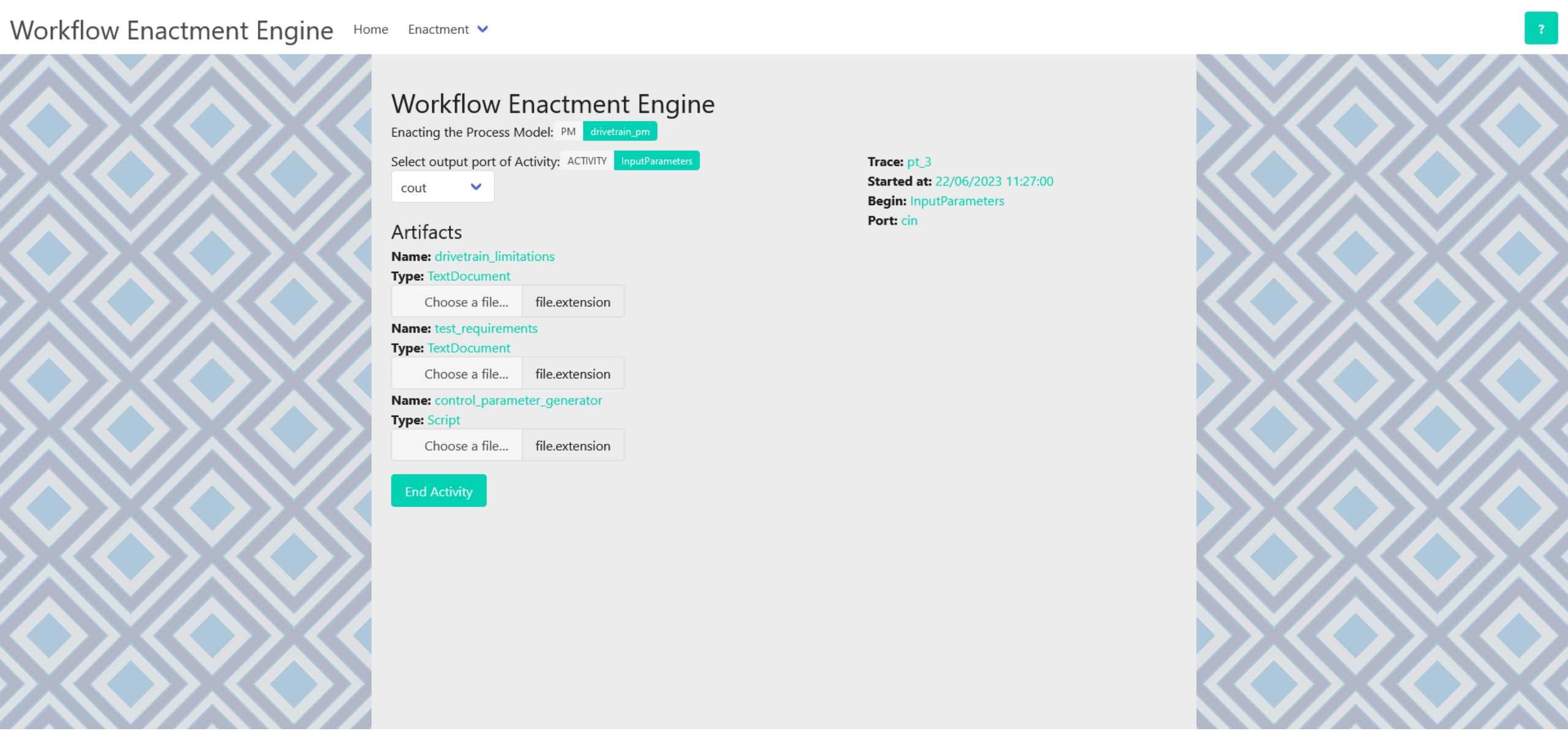
Trace visualisation

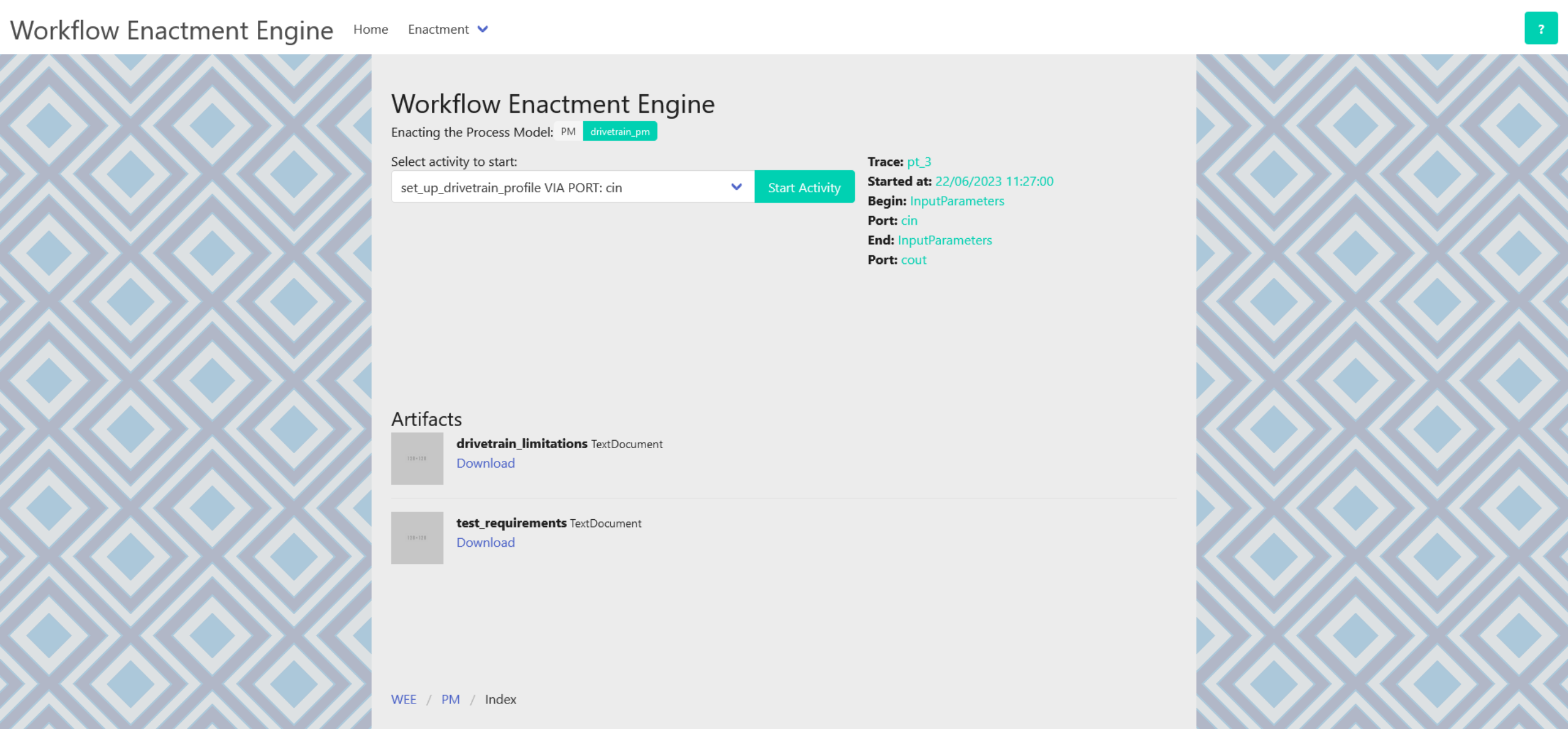
Graph Exploring Tool

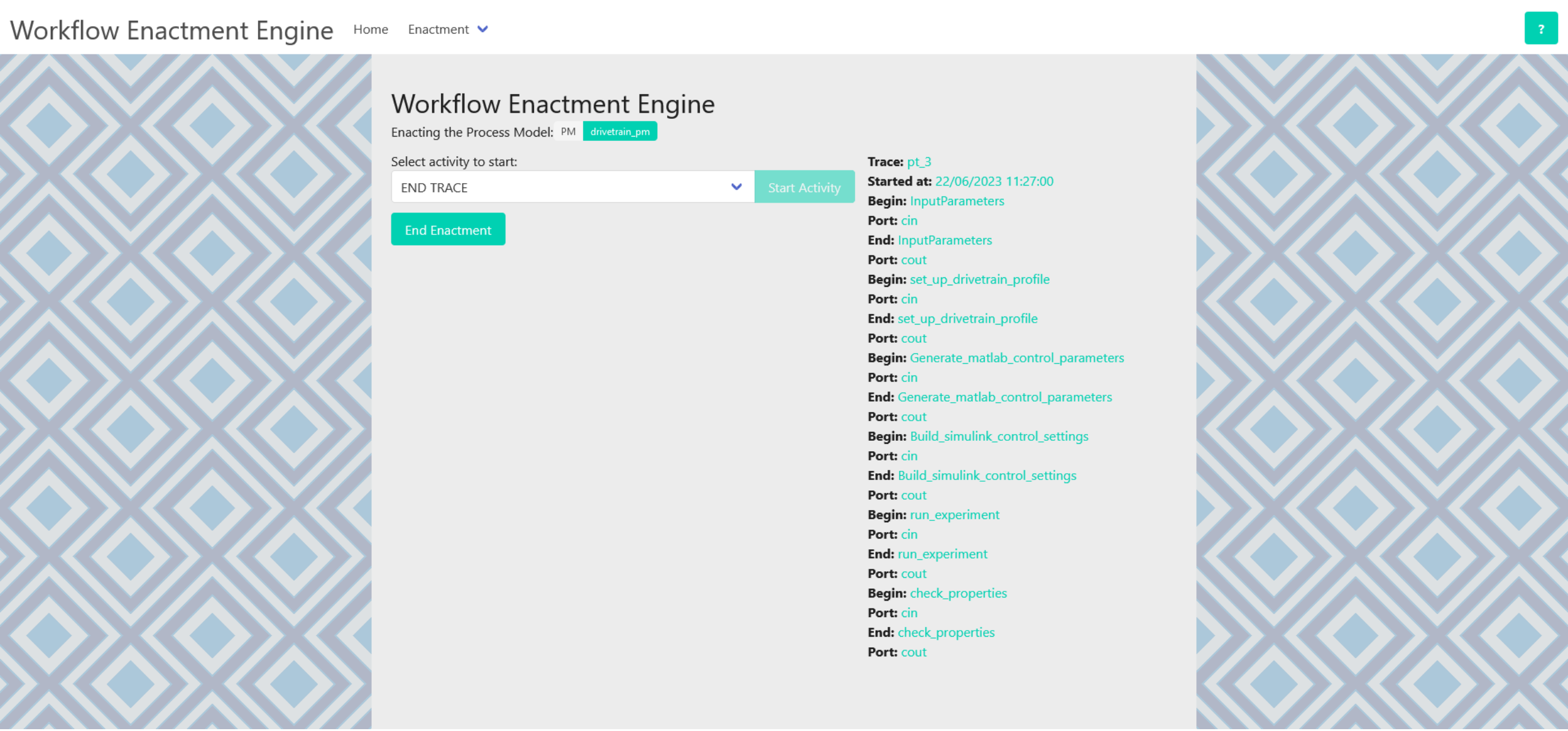

demo.drawio
File Edit View Arrange Extras Help All changes saved
Share
Search Shapes
Scratchpad
Drag elements here
FTG+PM - Common
FTG+PM - FTG
FTG+PM - PM
FTG+PM - Trace
FTG+PM - S/S
General
+ More Shapes
Knowledge Graph...
Create traceability link to...
Undo
Clear Default Style
Select All
Select Vertices
Select Edges
rec
cin
DefineCBDModel
din
dout
cout
CBD
Sketch
sketch
xopp
RunCBDSimulation
CreateRequirements
LookAtSketch
ValidateCBDSimulationResults
ok
notOk
Script
GenerateControlParameter
Profile
SetupProfile
cinRec
TabularData
imabox
MyPM:pm
AnotherPM:pm
FTG:ftg
ModelVerse
FTG:ftg Open
MinimalPM:pm Open
PM Enactment: Start New...
MyPM:pm Open
Open "pt_1" (ongoing)
Open "start_trace_event" (finished)
MyPMRec:pm Open
SpringDamperSimulation:pm Open
Open "pt_0" (ongoing)
drivetrain:pm Open
Diagram
Style
View
Grid
10 pt
Page View
Background
Change...
Background Color
Shadow
Sketch
Options
Connection Arrows
Connection Points
Guides
Paper Size
US-Letter (8,5" x 11")
Portrait
Landscape
Edit Data...
Clear Default Style


Workflow Enactment Engine
Home
Enactment
?
Wee: Workflow Enactment Engine
Choose the Process Model to be enacted:
drivetrain_pm
New Enactment
Continue enactment:
select trace
Continue Enactment
WEE / PM / Index


Workflow Enactment Engine
Home
Enactment
?
Workflow Enactment Engine
Enacting the Process Model: PM drivetrain_pm
Select activity to start:
InputParameters VIA PORT: cin
Start Activity
Trace: pt_3
Started at: 22/06/2023 11:27:00
WEE / PM / Index


Workflow Enactment Engine
Home
Enactment
?
Workflow Enactment Engine
Enacting the Process Model: PM drivetrain_pm
Select output port of Activity: ACTIVITY InputParameters
cout
Artifacts
Name: drivetrain_limitations
Type: TextDocument
Choose a file...
file.extension
Name: test_requirements
Type: TextDocument
Choose a file...
file.extension
Name: control_parameter_generator
Type: Script
Choose a file...
file.extension
End Activity
Trace: pt_3
Started at: 22/06/2023 11:27:00
Begin: InputParameters
Port: cin


Workflow Enactment Engine
Home
Enactment
?
Workflow Enactment Engine
Enacting the Process Model: PM drivetrain_pm
Select activity to start:
set_up_drivetrain_profile VIA PORT: cin
Start Activity
Trace: pt_3
Started at: 22/06/2023 11:27:00
Begin: InputParameters
Port: cin
End: InputParameters
Port: cout
Artifacts
drivetrain_limitations TextDocument
Download
test_requirements TextDocument
Download
WEE / PM / Index


Workflow Enactment Engine
Home
Enactment
?
Workflow Enactment Engine
Enacting the Process Model: PM drivetrain_pm
Select activity to start:
END TRACE
Start Activity
End Enactment
Trace: pt_3
Started at: 22/06/2023 11:27:00
Begin: InputParameters
Port: cin
End: InputParameters
Port: cout
Begin: set_up_drivetrain_profile
Port: cin
End: set_up_drivetrain_profile
Port: cout
Begin: Generate_matlab_control_parameters
Port: cin
End: Generate_matlab_control_parameters
Port: cout
Begin: Build_simulink_control_settings
Port: cin
End: Build_simulink_control_settings
Port: cout
Begin: run_experiment
Port: cin
End: run_experiment
Port: cout
Begin: check_properties
Port: cin
End: check_properties
Port: cout

Workflow Enactment Engine

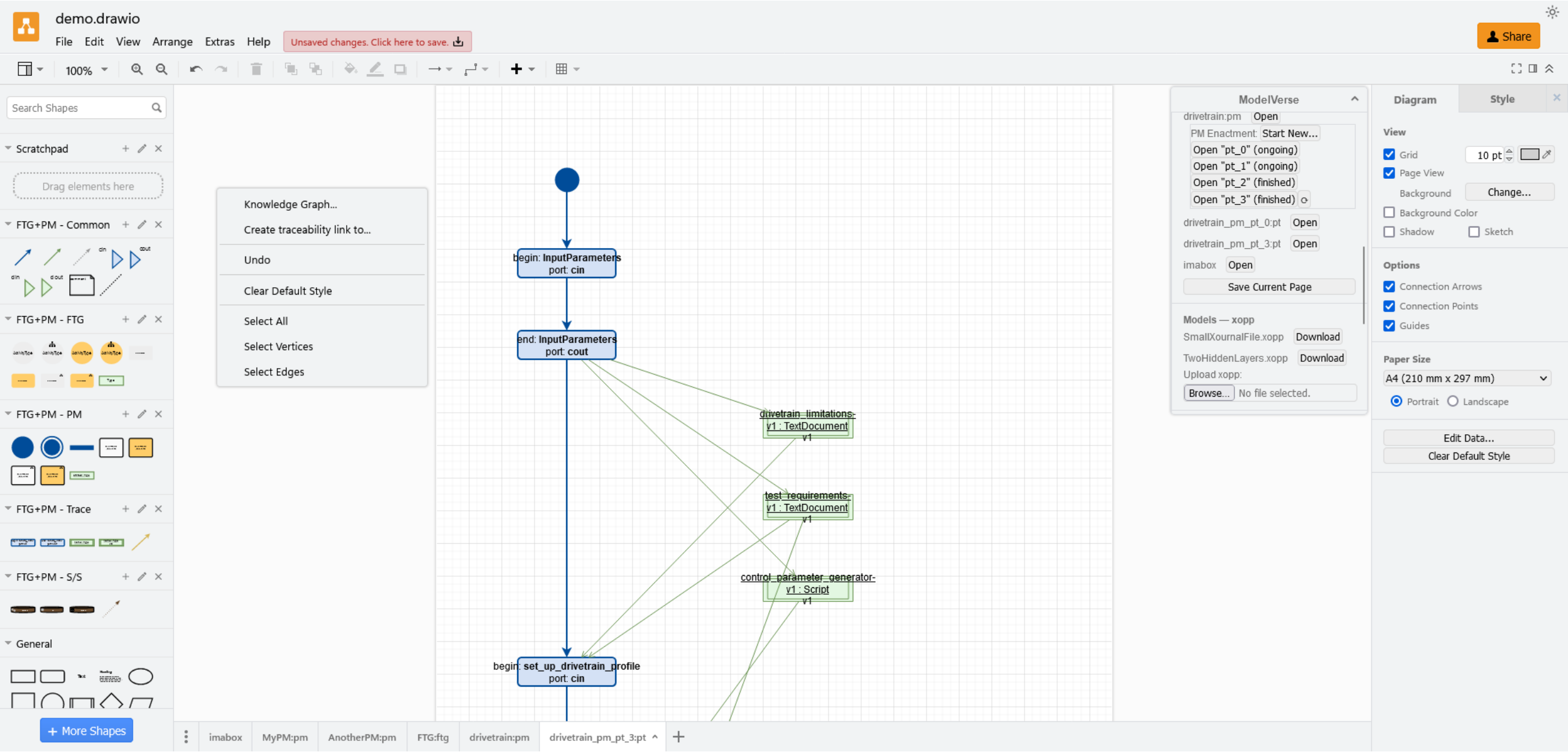
Enactment of the Process Model: drivetrain_pm has ended!

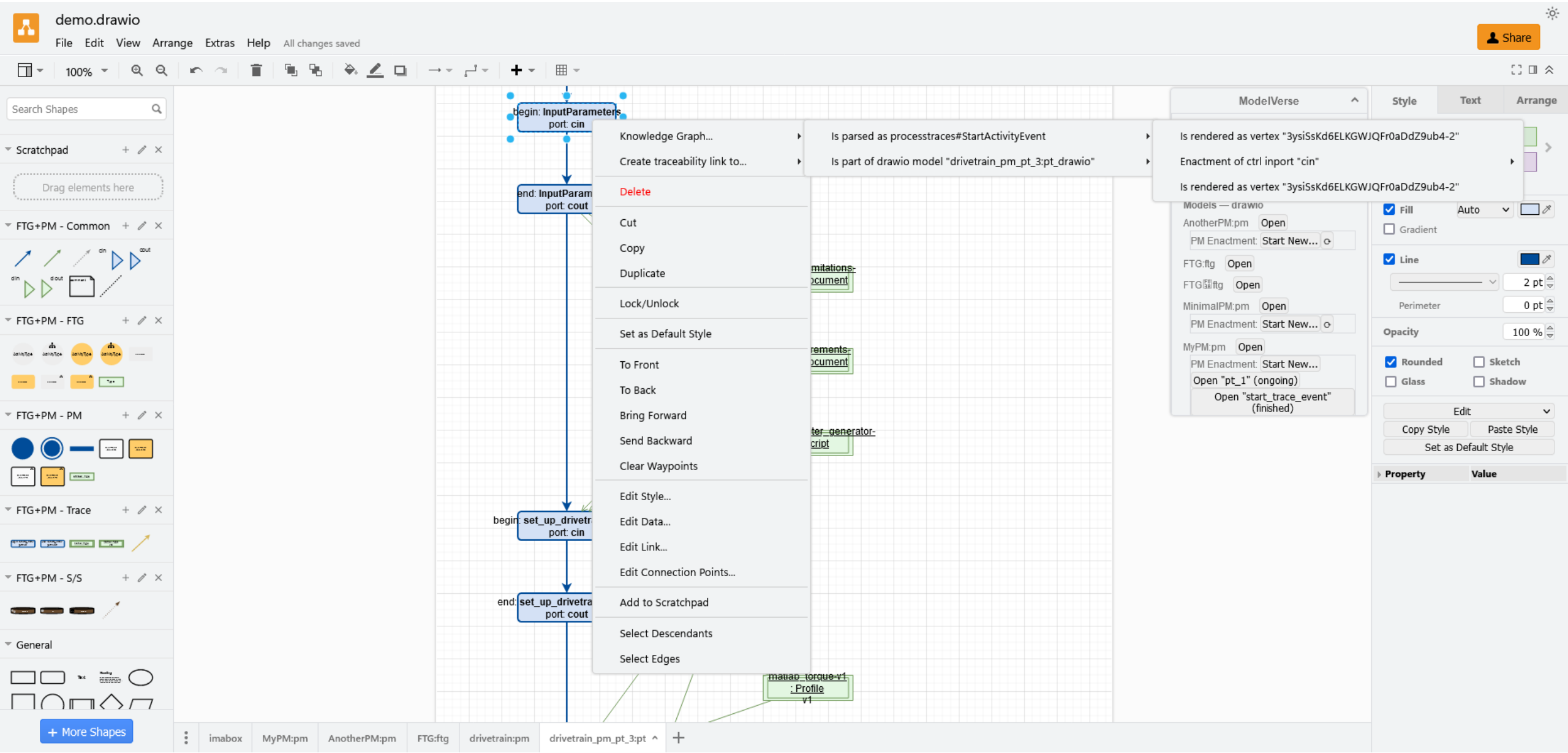
HOME

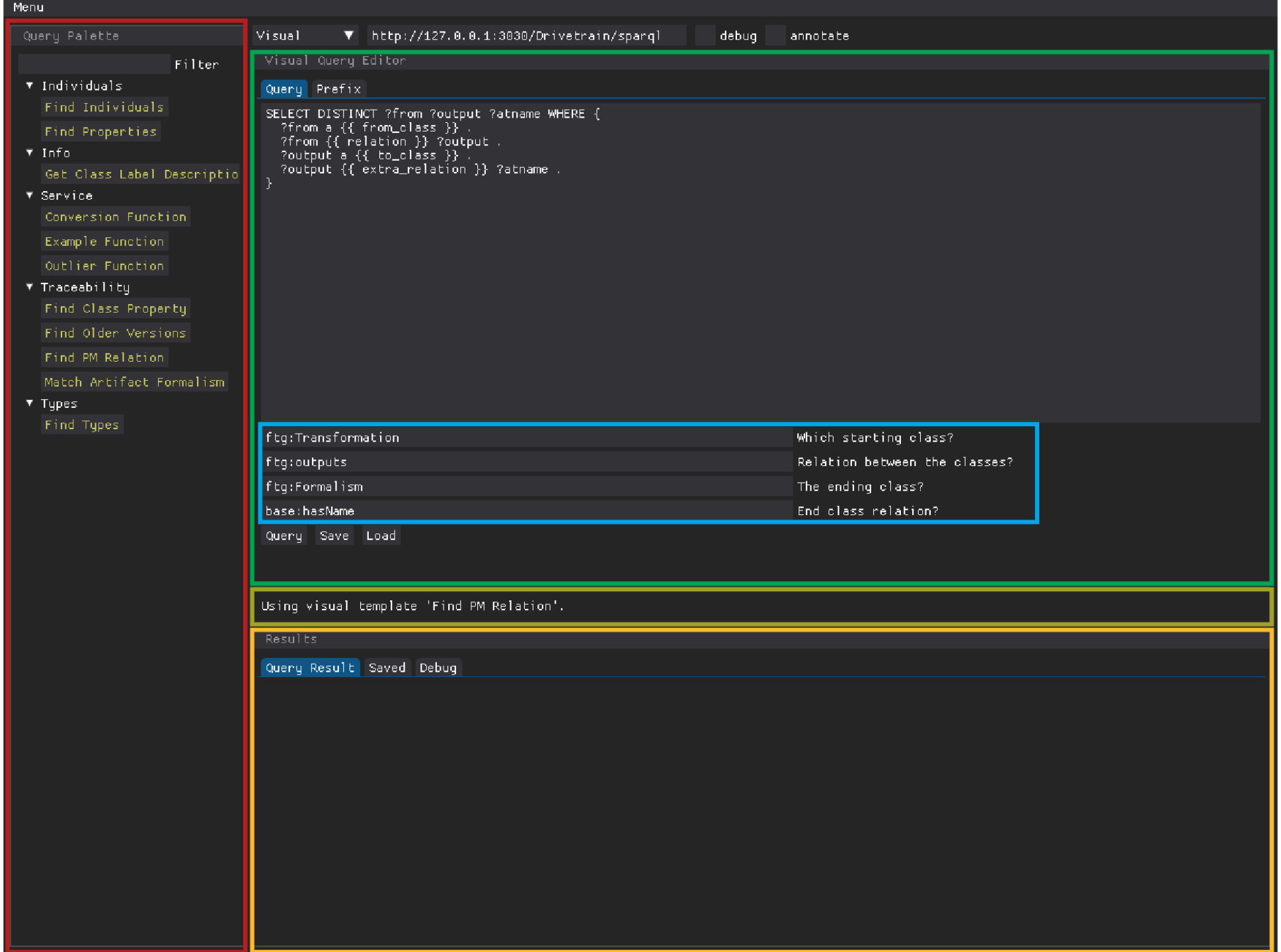
Trace: pt_3

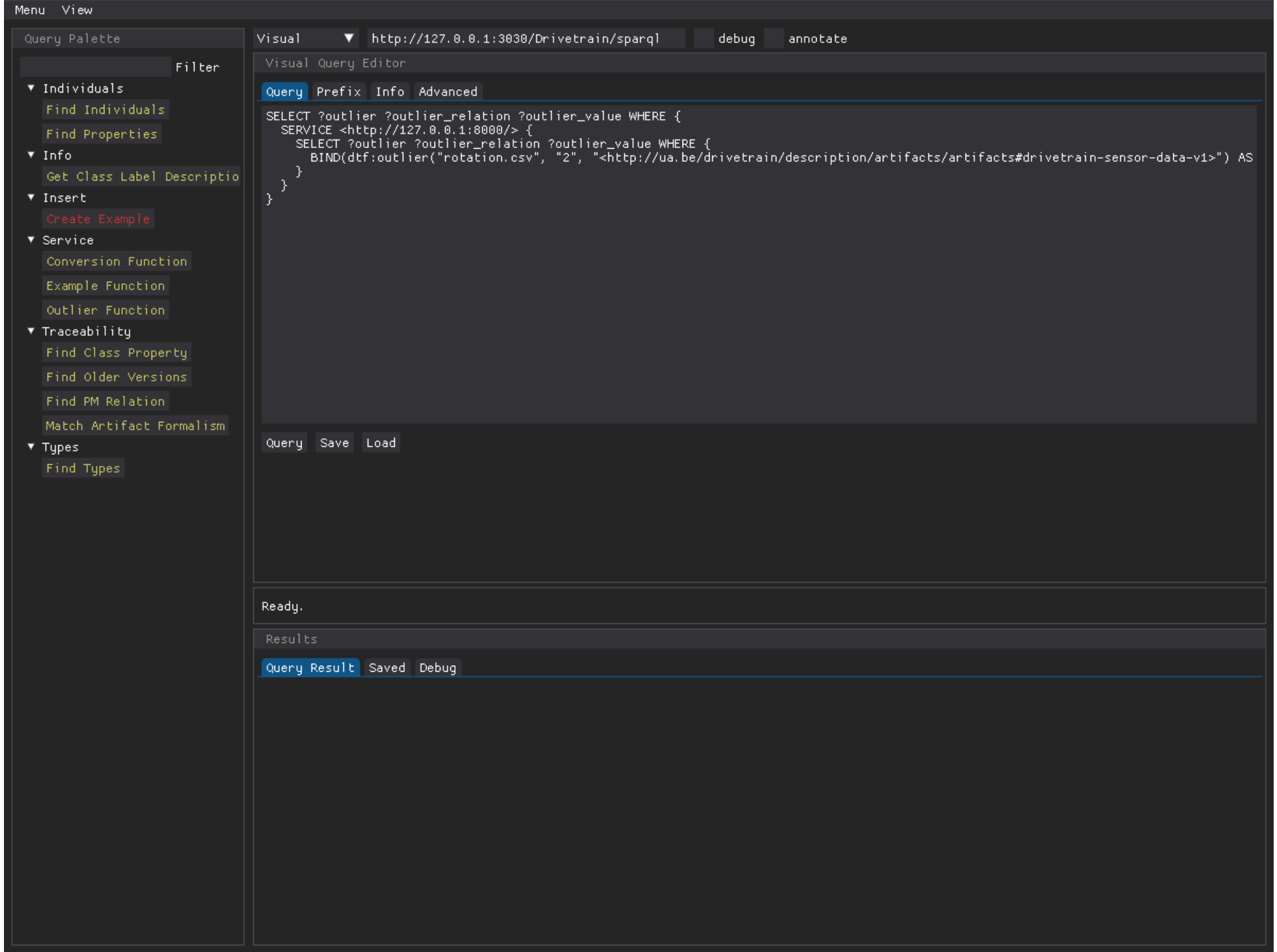
Started at: 22/06/2023 11:27:00

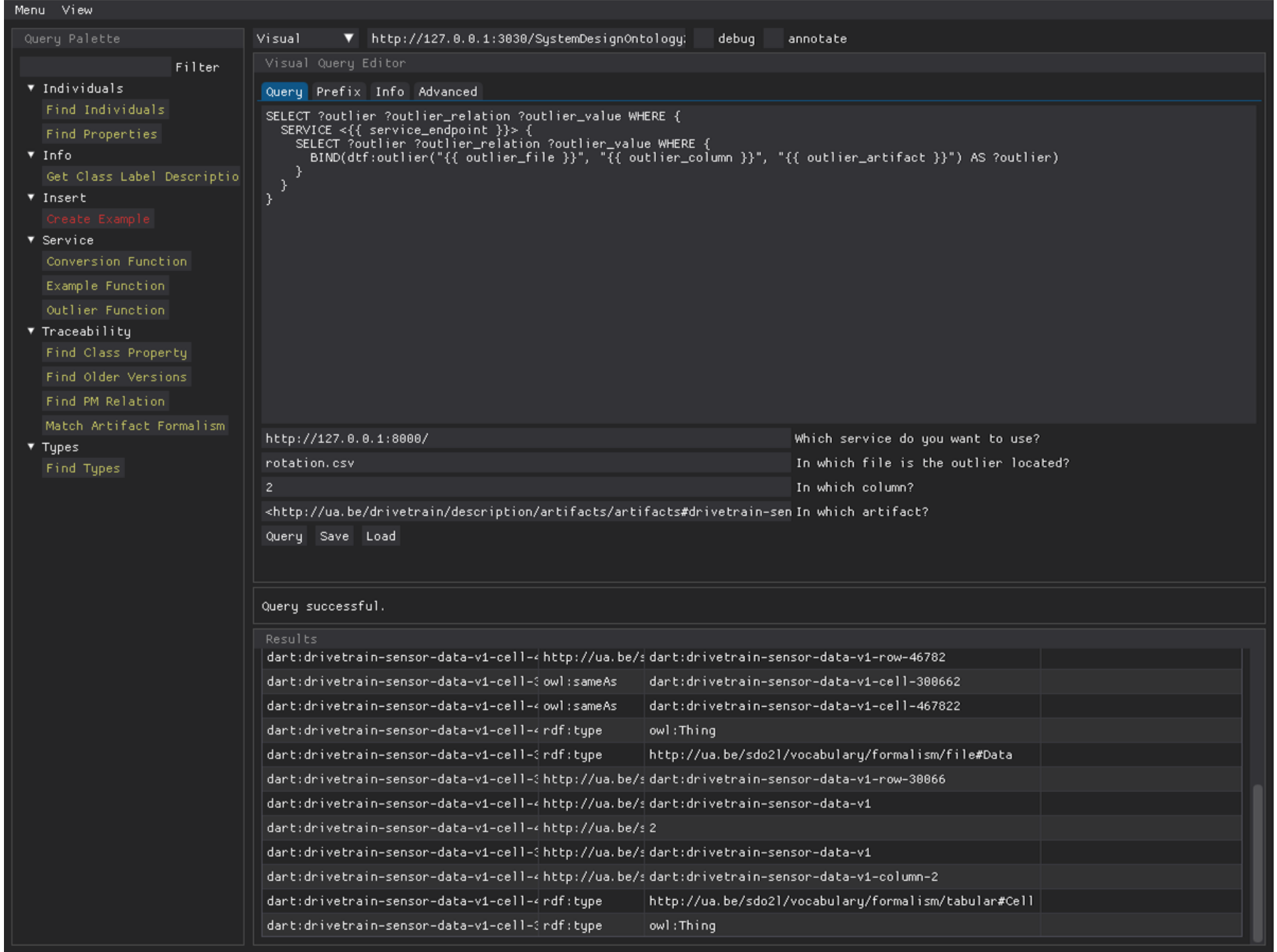
Begin:
InputParameters
port: cin
End:
InputParameters
port: cout
Begin:
set_up_drivetrain_profile
port: cin
End:
set_up_drivetrain_profile
port: cout
Begin:
Generate_matlab_control_parameters
port: cin
End:
Generate_matlab_control_parameters
port: cout
Begin:
Build_simulink_control_settings
port: cin
End:
Build_simulink_control_settings
port: cout
Begin:
run_experiment
port: cin


demo.drawio
File Edit View Arrange Extras Help
Unsaved changes. Click here to save.
Share
100%
Search Shapes
Scratchpad
Drag elements here
FTG+PM - Common
FTG+PM - FTG
FTG+PM - PM
FTG+PM - Trace
FTG+PM - S/S
General
+ More Shapes
Knowledge Graph...
Create traceability link to...
Undo
Clear Default Style
Select All
Select Vertices
Select Edges
begin: InputParameters
port: cin
end: InputParameters
port: cout
drivetrain_limitations-
v1 : TextDocument
v1
test_requirements-
v1 : TextDocument
v1
control_parameter_generator-
v1 : Script
v1
begin: set_up_drivetrain_profile
port: cin
ModelVerse
drivetrain:pm Open
PM Enactment: Start New...
Open "pt_0" (ongoing)
Open "pt_1" (ongoing)
Open "pt_2" (finished)
Open "pt_3" (finished)
drivetrain_pm_pt_0:pt Open
drivetrain_pm_pt_3:pt Open
imabox Open
Save Current Page
Models — xopp
SmallXournalFile.xopp Download
TwoHiddenLayers.xopp Download
Upload xopp:
Browse... No file selected.
Diagram
Style
View
Grid 10 pt
Page View
Background Change...
Background Color
Shadow
Sketch
Options
Connection Arrows
Connection Points
Guides
Paper Size
A4 (210 mm x 297 mm)
Portrait
Landscape
Edit Data...
Clear Default Style
imabox
MyPM:pm
AnotherPM:pm
FTG:ftg
drivetrain:pm
drivetrain_pm_pt_3:pt


demo.drawio
File Edit View Arrange Extras Help All changes saved
Share
100%
Search Shapes
Scratchpad
Drag elements here
FTG+PM - Common
FTG+PM - FTG
FTG+PM - PM
FTG+PM - Trace
FTG+PM - S/S
General
+ More Shapes
begin: InputParameters
port: cin
end: InputParam
port: cout
begin: set_up_drivetr
port: cin
end: set_up_drivetra
port: cout
matlab_torque-v1
: Profile
v1
Knowledge Graph...
Create traceability link to...
Delete
Cut
Copy
Duplicate
Lock/Unlock
Set as Default Style
To Front
To Back
Bring Forward
Send Backward
Clear Waypoints
Edit Style...
Edit Data...
Edit Link...
Edit Connection Points...
Add to Scratchpad
Select Descendants
Select Edges
Is parsed as processtraces#StartActivityEvent
Is part of drawio model "drivetrain_pm_pt_3:pt_drawio"
Is rendered as vertex "3ysiSsKd6ELKGWJQFr0aDdZ9ub4-2"
Enactment of ctrl inport "cin"
Is rendered as vertex "3ysiSsKd6ELKGWJQFr0aDdZ9ub4-2"
ModelVerse
Models — drawio
AnotherPM:pm Open
PM Enactment: Start New...
FTG:ftg Open
FTG:ftg Open
MinimalPM:pm Open
PM Enactment: Start New...
MyPM:pm Open
PM Enactment: Start New...
Open "pt_1" (ongoing)
Open "start_trace_event" (finished)
Style
Text
Arrange
Fill
Auto
Gradient
Line
2 pt
Perimeter
0 pt
Opacity
100 %
Rounded
Sketch
Glass
Shadow
Edit
Copy Style
Paste Style
Set as Default Style
Property
Value
imabox
MyPM:pm
AnotherPM:pm
FTG:ftg
drivetrain:pm
drivetrain_pm_pt_3:pt


Menu
Query Palette
Filter
Individuals
Find Individuals
Find Properties
Info
Get Class Label Descriptio
Service
Conversion Function
Example Function
Outlier Function
Traceability
Find Class Property
Find Older Versions
Find PM Relation
Match Artifact Formalism
Types
Find Types
Visual
http://127.0.0.1:3030/Drivetrain/sparql
debug
annotate
Visual Query Editor
Query
Prefix
SELECT DISTINCT ?from ?output ?atname WHERE {
?from a {{ from_class }} .
?from {{ relation }} ?output .
?output a {{ to_class }} .
?output {{ extra_relation }} ?atname .
}
ftg:Transformation
Which starting class?
ftg:outputs
Relation between the classes?
ftg:Formalism
The ending class?
base:hasName
End class relation?
Query
Save
Load
Using visual template 'Find PM Relation'.
Results
Query Result
Saved
Debug


Menu View
Query Palette
Filter
Individuals
Find Individuals
Find Properties
Info
Get Class Label Descriptio
Insert
Create Example
Service
Conversion Function
Example Function
Outlier Function
Traceability
Find Class Property
Find Older Versions
Find PM Relation
Match Artifact Formalism
Types
Find Types
Visual
http://127.0.0.1:3030/Drivetrain/sparql
debug
annotate
Visual Query Editor
Query
Prefix
Info
Advanced
SELECT ?outlier ?outlier_relation ?outlier_value WHERE {
SERVICE <http://127.0.0.1:8000/> {
SELECT ?outlier ?outlier_relation ?outlier_value WHERE {
BIND(dtf:outlier("rotation.csv", "2", "<http://ua.be/drivetrain/description/artifacts/artifacts#drivetrain-sensor-data-v1>") AS
}
}
}
Query
Save
Load
Ready.
Results
Query Result
Saved
Debug


Menu View
Query Palette
Filter
Individuals
Find Individuals
Find Properties
Info
Get Class Label Descriptio
Insert
Create Example
Service
Conversion Function
Example Function
Outlier Function
Traceability
Find Class Property
Find Older Versions
Find PM Relation
Match Artifact Formalism
Types
Find Types
Visual
http://127.0.0.1:3030/SystemDesignOntology
debug
annotate
Visual Query Editor
Query
Prefix
Info
Advanced
SELECT ?outlier ?outlier_relation ?outlier_value WHERE {
SERVICE <{{ service_endpoint }}> {
SELECT ?outlier ?outlier_relation ?outlier_value WHERE {
BIND(dtf:outlier("{{ outlier_file }}", "{{ outlier_column }}", "{{ outlier_artifact }}") AS ?outlier)
}
}
}
http://127.0.0.1:8000/
Which service do you want to use?
rotation.csv
In which file is the outlier located?
2
In which column?
<http://ua.be/drivetrain/description/artifacts/artifacts#drivetrain-sen
In which artifact?
Query
Save
Load
Query successful.
Results
dart:drivetrain-sensor-data-v1-cell-4 http://ua.be/s dart:drivetrain-sensor-data-v1-row-46782
dart:drivetrain-sensor-data-v1-cell-3 owl:sameAs dart:drivetrain-sensor-data-v1-cell-300662
dart:drivetrain-sensor-data-v1-cell-4 owl:sameAs dart:drivetrain-sensor-data-v1-cell-467822
dart:drivetrain-sensor-data-v1-cell-4 rdf:type owl:Thing
dart:drivetrain-sensor-data-v1-cell-3 rdf:type http://ua.be/sdo2l/vocabulary/formalism/file#Data
dart:drivetrain-sensor-data-v1-cell-3 http://ua.be/s dart:drivetrain-sensor-data-v1-row-30066
dart:drivetrain-sensor-data-v1-cell-4 http://ua.be/s dart:drivetrain-sensor-data-v1
dart:drivetrain-sensor-data-v1-cell-4 http://ua.be/s 2
dart:drivetrain-sensor-data-v1-cell-3 http://ua.be/s dart:drivetrain-sensor-data-v1
dart:drivetrain-sensor-data-v1-cell-4 http://ua.be/s dart:drivetrain-sensor-data-v1-column-2
dart:drivetrain-sensor-data-v1-cell-4 rdf:type http://ua.be/sdo2l/vocabulary/formalism/tabular#Cell
dart:drivetrain-sensor-data-v1-cell-3 rdf:type owl:Thing

We’re currently looking into

Increasing the middleware transparency

Adding automated activities

Doing performance modelling


University
of Antwerp