Standardized Exchange of Information Between Geometry and Physics-based Modeling

Utilizing Selected Data-driven Model Structures

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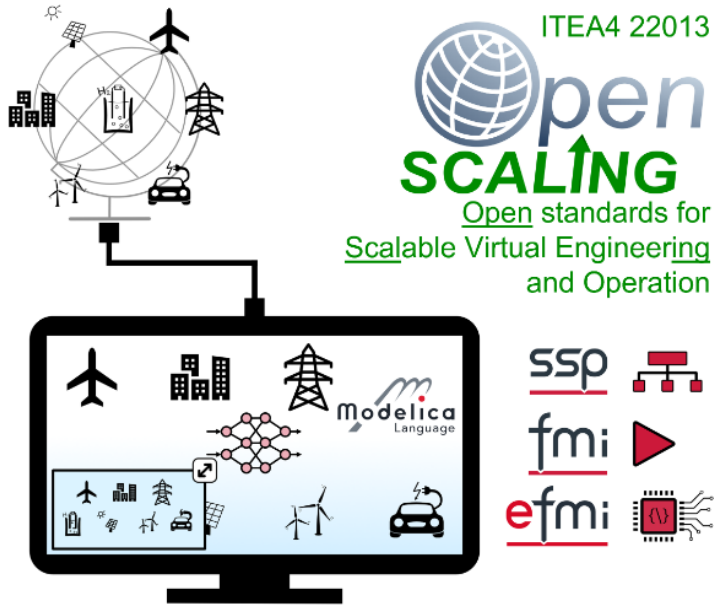
Agenda

- Introduction
- Aim and Research questions
- Method
- Theory
- Proposed Methodology
- Geometric Models
- Extraction of Parameters from Geometric Models
- Machine Learning
- Extraction of Parameters from Machine Learning
- Conclusion and Future Work

https://thumbs.dreamstime.com/b/d-business-man-presenting-concept-agenda-white-background-36110030.jpg

Introduction

- OpenSCALING project
- Data-driven approach to the design and analysis of aircraft fuel system
- Open standards are utilized



https://incquery.io/research-projects/openscaling

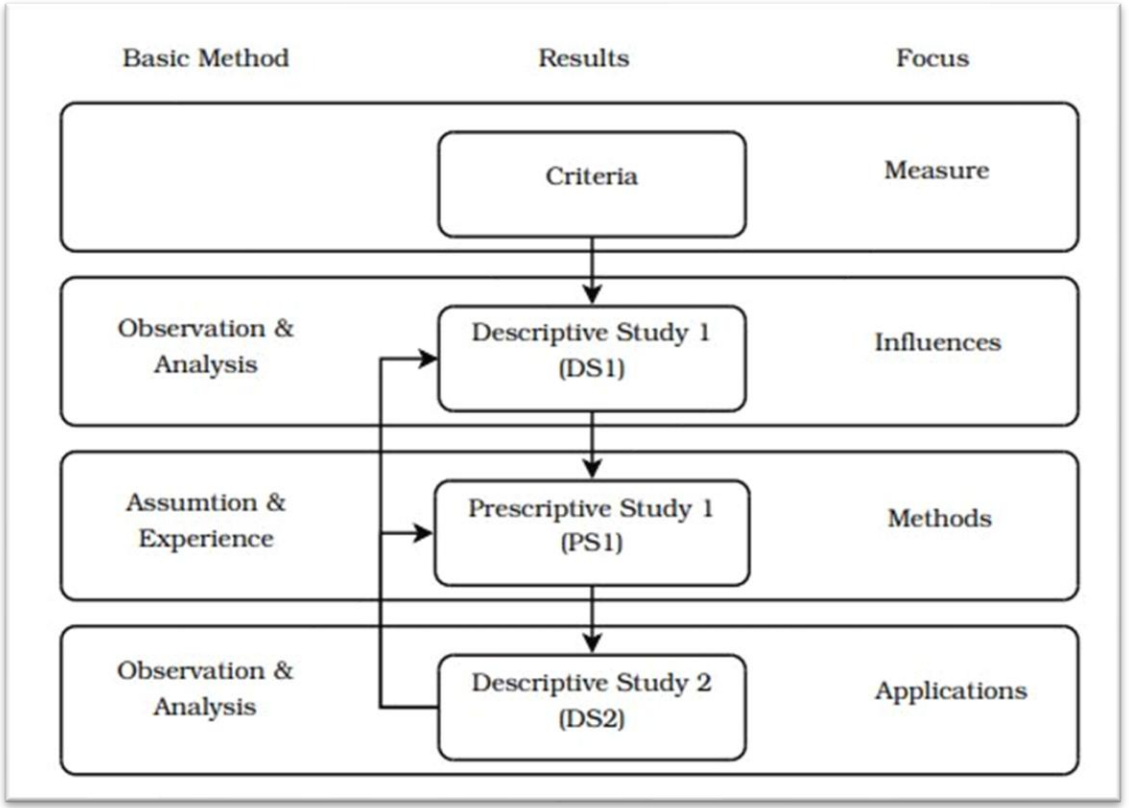
Aim and Research questions

The aim of this research is evaluating data transfer applications used in aircraft fuel system simulations to improve the interoperability between geometric data and simulation tools.

- **RQ1:** How can tool-independent standards be leveraged to enhance interoperability between system simulation and geometric modeling in a data transfer process, specifically regarding accuracy?
- **RQ2:** Which methods can be used to improve traceability and ensure better tracking of data lineage between geometric models and dynamic simulations?

Design Research Method

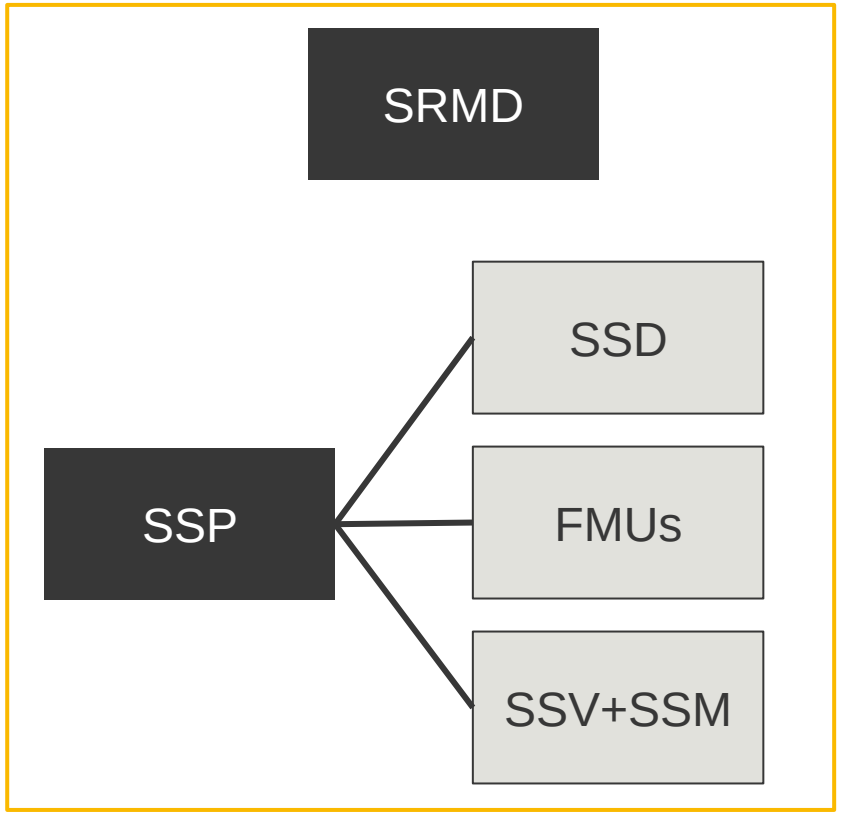
- *Criteria* - Effectiveness of the overall research
- *DS1* - Analyze the problem
- *PS1* - Identify and develop potential methods
- *DS2* - Evaluate the methods



Theory

FMI – Functional Mock-up Interface
FMU – Functional Mock-up Unit
SSP – System Structure and Parameterization
SSD – System Structure Description
SSM – System Structure Mapping
SRMD – Simulation Resource meta-data

- Standardized data exchange
- FMI
  - Packaging of single simulations models within a FMU
- SSP
  - Packaging of multiple simulation models including associated parameters at any system level
- SSP Traceability
  - Utilized to improve traceability for simulation models
  - SRMD



Approaches

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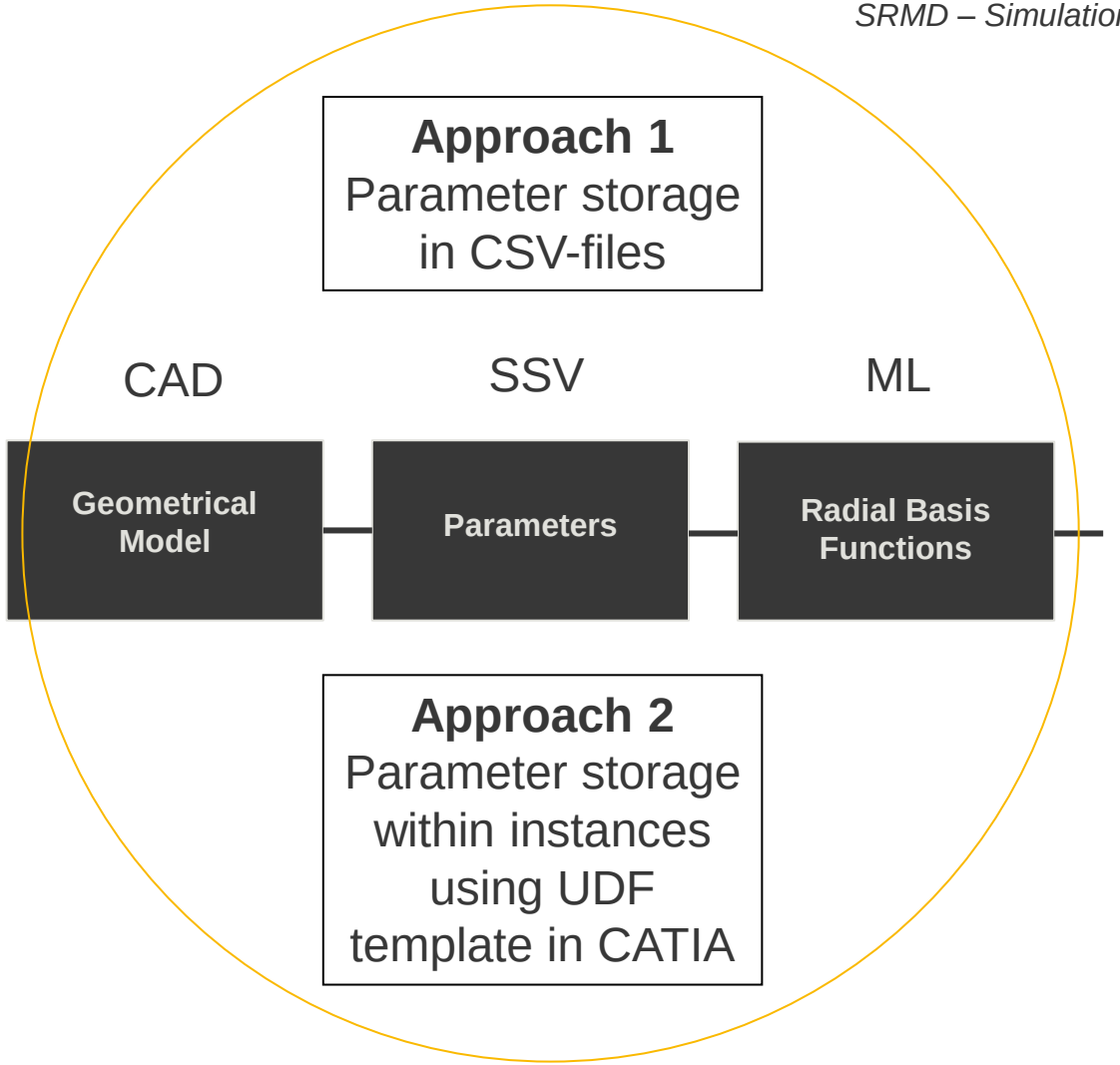
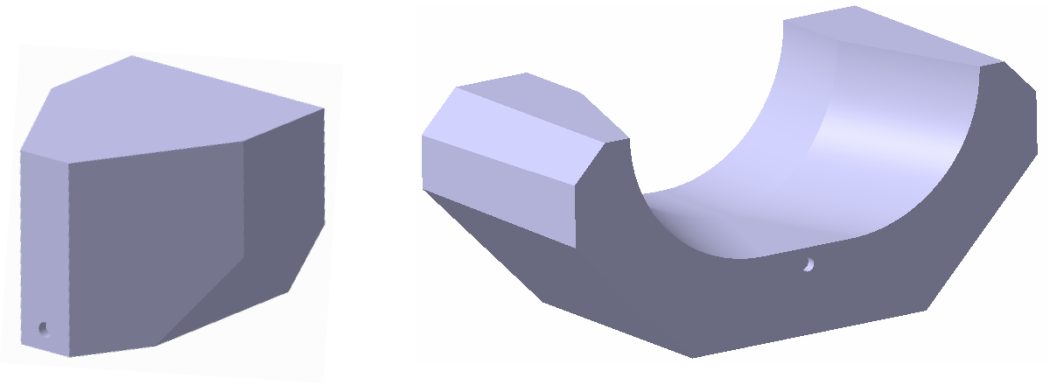


Approach	Pros (+)	Cons (-)
1	• Streamlined and flexible workflow • Fast data extraction and manipulation	• Not a standardized method for parameter extraction
2	• Compatible with the SSP standard and ensures consistency • Traceability	• Time consuming due to the additional steps required within CATIA

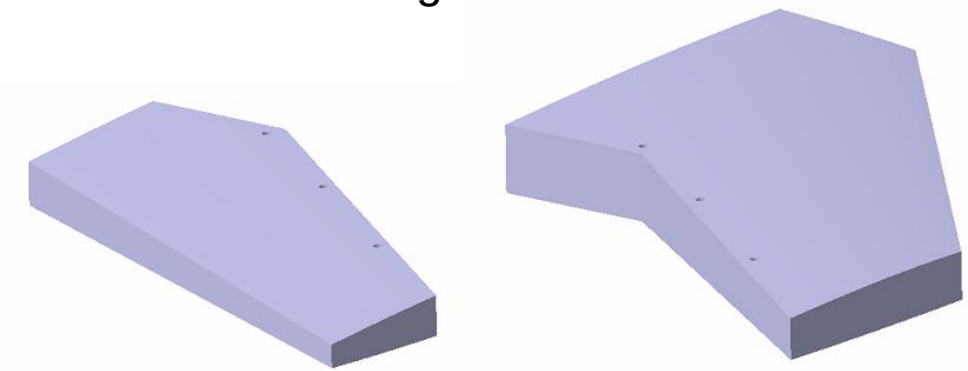
To optimize the workflow, the amount of instances has been reduced from ~70 000 to 1200

Geometric Models

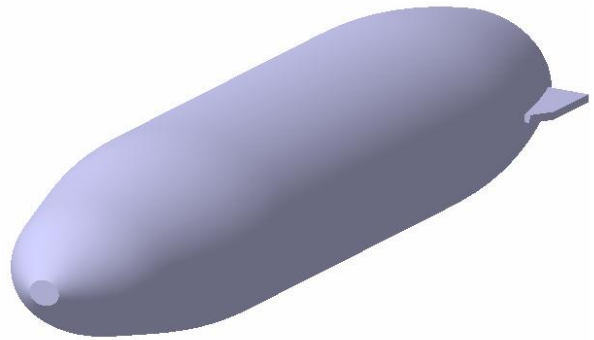
Fuselage



Wings

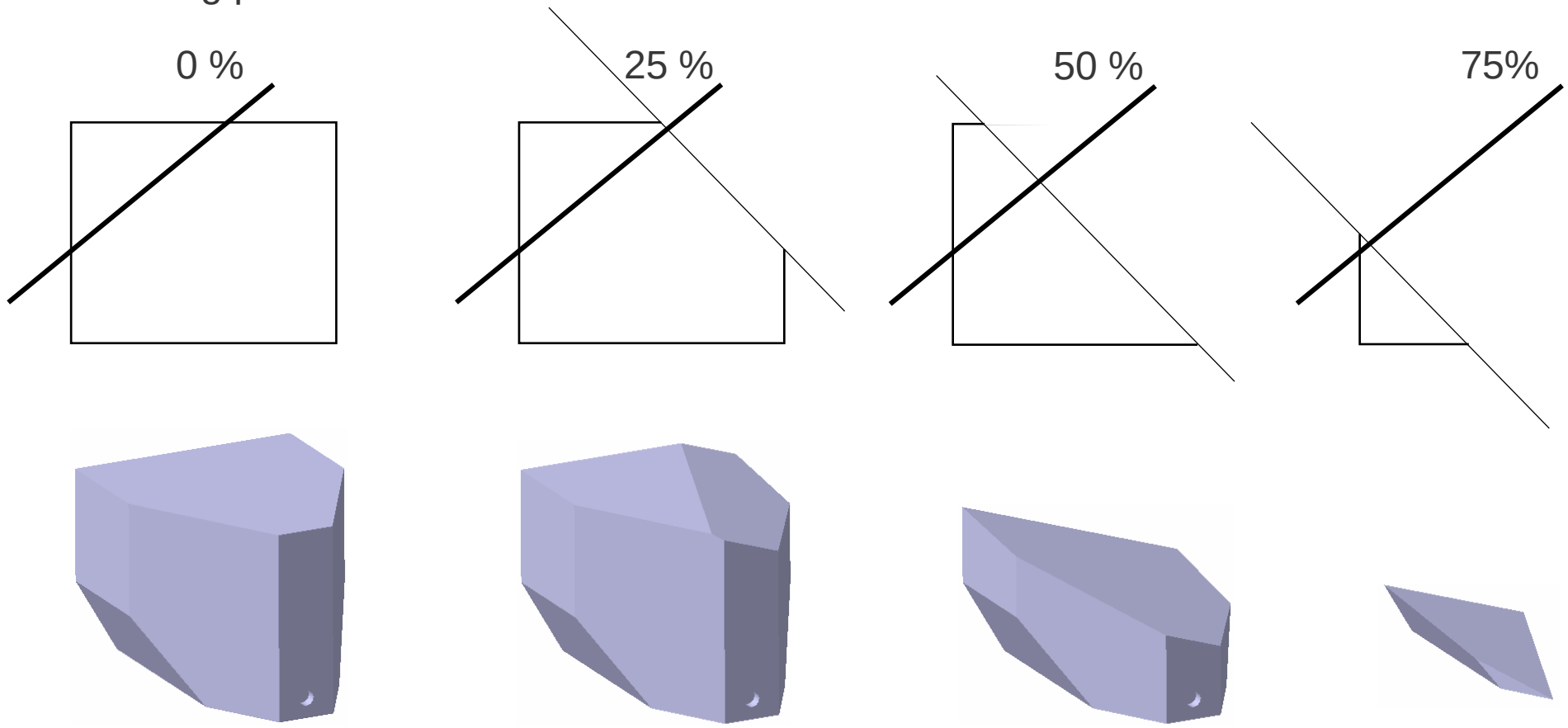


External



Split Function

Acceleration vector: ——
Cutting plane: ——



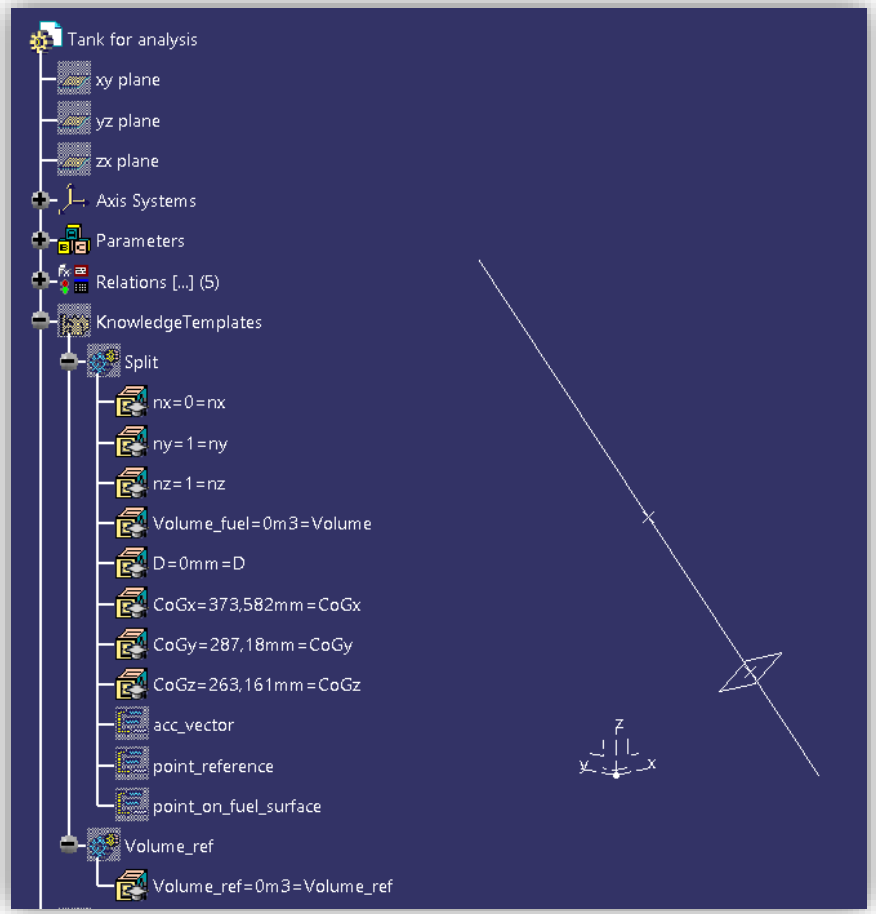
Extracting Parameters to ML: Approach 1 – CSV file

n_x; n_y; n_z; VolumeFuel; CoGx; CoGy; CoGz; D; VolumeRef = 1,20950459778775; Tank_Center_x = 6347,791; Tank_Center_y = 0; Tank_Center_z = 11812,5;

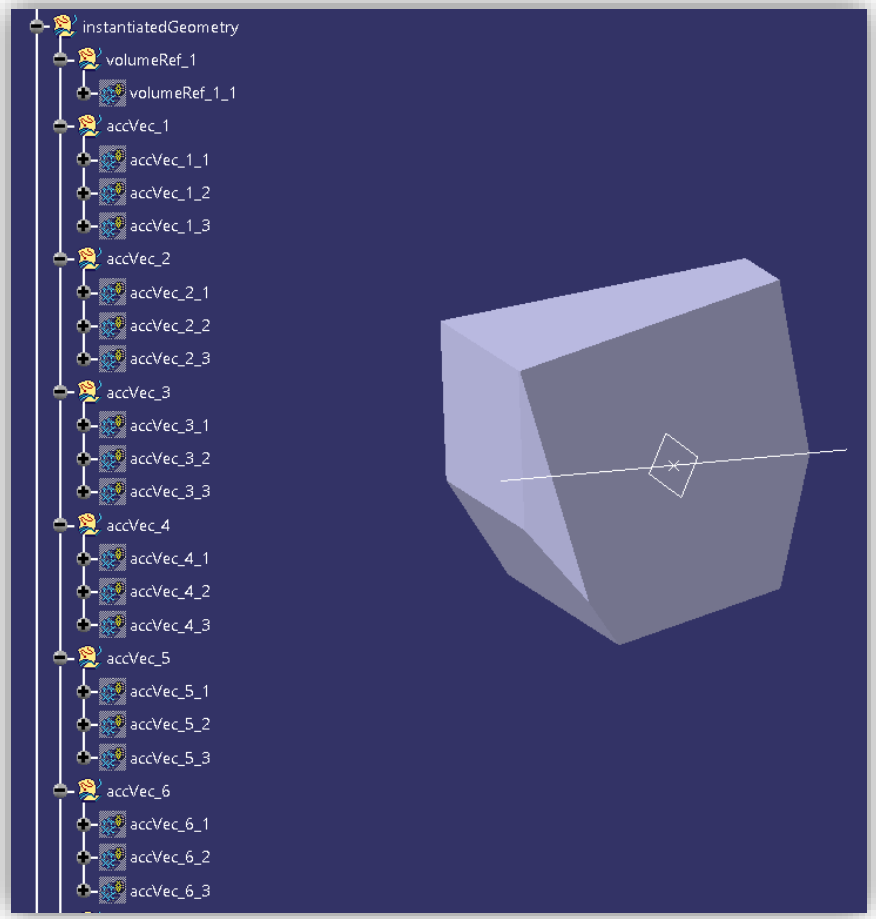
0.7198;0.4625;0.51767;0.314593515374361;6496.89447419825;764.916040203295;11969.8248629192;268.278244746772;
0.55609;-0.20008;-0.80668;0.947462510173661;6392.49057184007;-157.217108181353;11740.1953573125;223.721568557405;
-0.35137;-0.32021;-0.87977;7.26726128306146E-04;5845.7642769445;-543.2955905502;11419.0368454143;-680.278533447127;
-0.78183;0.10827;-0.61402;0.488036754533416;6086.59792130807;133.278499235304;11682.3467224237;-78.2785311349407;
0.94399;-0.32726;0.042159;1.1124674831112;6384.8576723017;-66.1194080745504;11807.5061768598;-533.721601341242;
…

Extracting Parameters to ML: Approach 2 – UDF Template

UDF Template and extracted parameters



Naming conventions



Extracting Parameters to ML - SSP 1.0

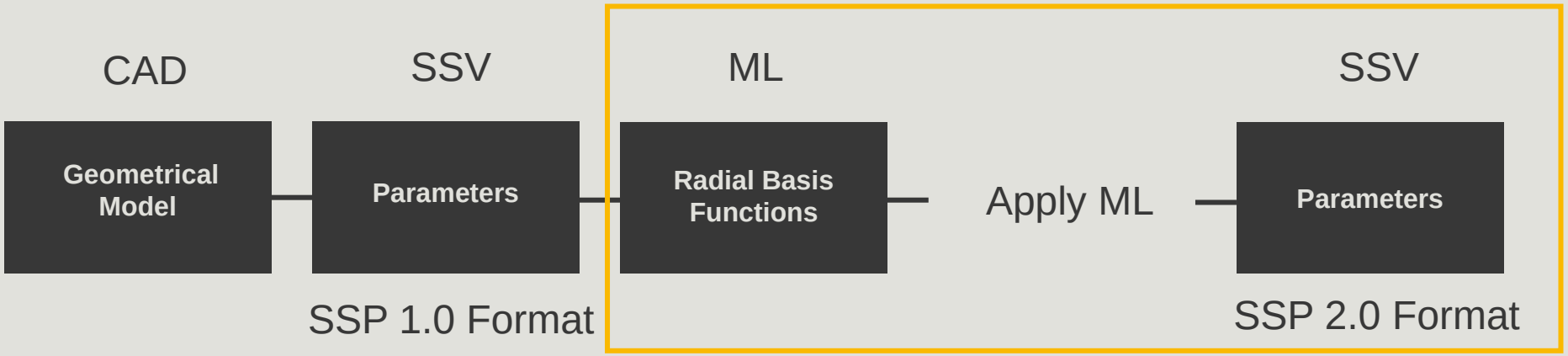
XML

```
<parameterSet name="accVec_1_3">
  <parameter name="nx" type="Double">
    <value>-0.11698</value>
    <unit>Unit Not Applicable</unit>
    <comment>Comment goes here</comment>
  </parameter>
  <parameter name="ny" type="Double">
    <value>-0.32139</value>
    <unit>Unit Not Applicable</unit>
    <comment>Comment goes here</comment>
  </parameter>
  <parameter name="nz" type="Double">
    <value>-0.93969</value>
    <unit>Unit Not Applicable</unit>
    <comment>Comment goes here</comment>
  </parameter>
  <parameter name="Volume" type="Double">
    <value>0.179472569829558</value>
    <unit>[m3]</unit>
    <comment>Comment goes here</comment>
  </parameter>
```

SSV

```
<ssv:Parameter name="part_'Tank for analysis'.geometricalSet_'instantiatedGeometry'.geometricalSet_'accVec_1'.parameterSet_'accVec_1_3'.parameter_'nx'">
  <ssv:Real unit="Unit Not Applicable" value="-0.11698"/>
</ssv:Parameter>
<ssv:Parameter name="part_'Tank for analysis'.geometricalSet_'instantiatedGeometry'.geometricalSet_'accVec_1'.parameterSet_'accVec_1_3'.parameter_'ny'">
  <ssv:Real unit="Unit Not Applicable" value="-0.32139"/>
</ssv:Parameter>
<ssv:Parameter name="part_'Tank for analysis'.geometricalSet_'instantiatedGeometry'.geometricalSet_'accVec_1'.parameterSet_'accVec_1_3'.parameter_'nz'">
  <ssv:Real unit="Unit Not Applicable" value="-0.93969"/>
</ssv:Parameter>
<ssv:Parameter name="part_'Tank for analysis'.geometricalSet_'instantiatedGeometry'.geometricalSet_'accVec_1'.parameterSet_'accVec_1_3'.parameter_'Volume'">
  <ssv:Real unit="[m3]" value="0.179472569829558"/>
</ssv:Parameter>
<ssv:Parameter name="part_'Tank for analysis'.geometricalSet_'instantiatedGeometry'.geometricalSet_'accVec_1'.parameterSet_'accVec_1_3'.parameter_'D'">
  <ssv:Real unit="[m]" value="6.94440974669554E-02"/>
</ssv:Parameter>
<ssv:Parameter name="part_'Tank for analysis'.geometricalSet_'instantiatedGeometry'.geometricalSet_'accVec_1'.parameterSet_'accVec_1_3'.parameter_'point_x'">
  <ssv:Real unit="[m]" value="0.404062"/>
</ssv:Parameter>
<ssv:Parameter name="part_'Tank for analysis'.geometricalSet_'instantiatedGeometry'.geometricalSet_'accVec_1'.parameterSet_'accVec_1_3'.parameter_'point_y'">
  <ssv:Real unit="[m]" value="0.311159"/>
</ssv:Parameter>
<ssv:Parameter name="part_'Tank for analysis'.geometricalSet_'instantiatedGeometry'.geometricalSet_'accVec_1'.parameterSet_'accVec_1_3'.parameter_'point_z'">
  <ssv:Real unit="[m]" value="0.332628"/>
</ssv:Parameter>
<ssv:Parameter name="part_'Tank for analysis'.geometricalSet_'instantiatedGeometry'.geometricalSet_'accVec_1'.parameterSet_'accVec_1_3'.parameter_'CoGx'">
  <ssv:Real unit="[m]" value="0.380295767922722"/>
</ssv:Parameter>
<ssv:Parameter name="part_'Tank for analysis'.geometricalSet_'instantiatedGeometry'.geometricalSet_'accVec_1'.parameterSet_'accVec_1_3'.parameter_'CoGy'">
  <ssv:Real unit="[m]" value="0.269548914170239"/>
</ssv:Parameter>
<ssv:Parameter name="part_'Tank for analysis'.geometricalSet_'instantiatedGeometry'.geometricalSet_'accVec_1'.parameterSet_'accVec_1_3'.parameter_'CoGz'">
  <ssv:Real unit="[m]" value="0.174909160902707"/>
```

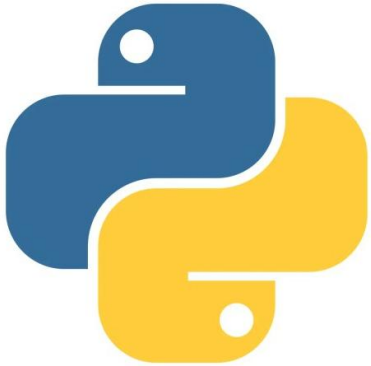
Proposed Methodology



VBA – Visual Basic for Applications
ML – Machine Learning

Machine Learning

- Python in Pycharm – Linux environment
- PySSP Standard
  - A Python library that allows for the creation, reading and editing of SSV, SSM and SSB files. In addition, it allows for the reading of SSP, FMU and SSD files.
- Radial Basis Functions:
  - Input parameters: *n_x, n_y, n_z* and *volume of fuel*
  - Output parameters: *GCx, GCy, GCz* and *D* (4 separate functions)
    - Number of centers (*n),* Weights (*W)* and Prescaler (σ) are saved for each output parameter
- The PySSP standard have been further developed to support SSV files in both SSP 1.0 and SSP 2.0 formats



https://i0.wp.com/junilearning.com/wp-content/uploads/2020/06/python-programming-language.webp?fit=800%2C800&ssl=1

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SRMD – Simulation Resource meta-data

Extracting Parameters from ML

SSP 1.0 Format

```
<?xml version='1.0' encoding='utf-8'?>
<ssv:ParameterSet xmlns:ssv=
"http://sspstandard.org/SSP1/SystemStructureParameterValues" version="1.0"
name="D_Fuel_Tank_1_1" generationTool="pyssp_standard" generationDateAndTime=
"2025-01-23T13:14:28.583104">
  <ssv:Parameters>
    <ssv:Parameter name="VolumeRef">
      <ssv:Real value="1.20950459778775" unit="m^3"/>
    </ssv:Parameter>
    <ssv:Parameter name="N_rD">
      <ssv:Integer value="252"/>
    </ssv:Parameter>
    <ssv:Parameter name="weight_0">
      <ssv:Real value="-0.08593060185474588" unit=""/>
    </ssv:Parameter>
    <ssv:Parameter name="weight_1">
      <ssv:Real value="-0.02910161179473955" unit=""/>
    </ssv:Parameter>
    <ssv:Parameter name="weight_2">
      <ssv:Real value="-0.04456052861465783" unit=""/>
    </ssv:Parameter>
    <ssv:Parameter name="weight_3">
      <ssv:Real value="-0.7697661191752928" unit=""/>
    </ssv:Parameter>
    ...
  </ssv:Parameters>
  <ssv:Units xmlns:ssc="http://ssp-standard.org/SSP1/SystemStructureCommon">
    <ssc:Unit name="m">
      <ssc:BaseUnit m="1"/>
    </ssc:Unit>
    <ssc:Unit name="m^3">
      <ssc:BaseUnit m="3"/>
    </ssc:Unit>
  </ssv:Units>
</ssv:ParameterSet>
```

Metadata

Parameters

Units

SSP 2.0 Format

```
<?xml version='1.0' encoding='utf-8'?>
<ssv:ParameterSet xmlns:ssv=
"http://sspstandard.org/SSP2/SystemStructureParameterValues" version="2.0"
name="D_Fuel_Tank_1_1" generationTool="pyssp_standard" generationDateAndTime=
"2025-01-29T12:48:34.381167">
  <ssv:Parameters>
    <ssv:Parameter name="VolumeRef">
      <ssv:Real value="1.20950459778775" unit="m^3"/>
    </ssv:Parameter>
    <ssv:Parameter name="N_rD">
      <ssv:Integer value="255"/>
    </ssv:Parameter>
    <ssv:Parameter name="CentersD">
      <ssv:Real value="[0.9931943598680439, -0.8382422608317056,...]" unit=""/>
    </ssv:Parameter>
    <ssv:Parameter name="PrescalerD">
      <ssv:Real value="[0.0263047042718215, 0.10026821582423856,...]" unit=""/>
    </ssv:Parameter>
    <ssv:Parameter name="WeightsD">
      <ssv:Real value="[-0.0894165236805315, -0.04270625074786133,...]" unit=""/>
    </ssv:Parameter>
    ...
  </ssv:Parameters>
  <ssv:Units xmlns:ssc="http://ssp-standard.org/SSP2/SystemStructureCommon">
    <ssc:Unit name="m">
      <ssc:BaseUnit m="1"/>
    </ssc:Unit>
    <ssc:Unit name="m^3">
      <ssc:BaseUnit m="3"/>
    </ssc:Unit>
  </ssv:Units>
</ssv:ParameterSet>
```

Arrays

Import SSV in SSP 1.0 Format into Dymola

Open ⟶ Import SSP ⟶ SSV Files ⟶ Select SSV file to import

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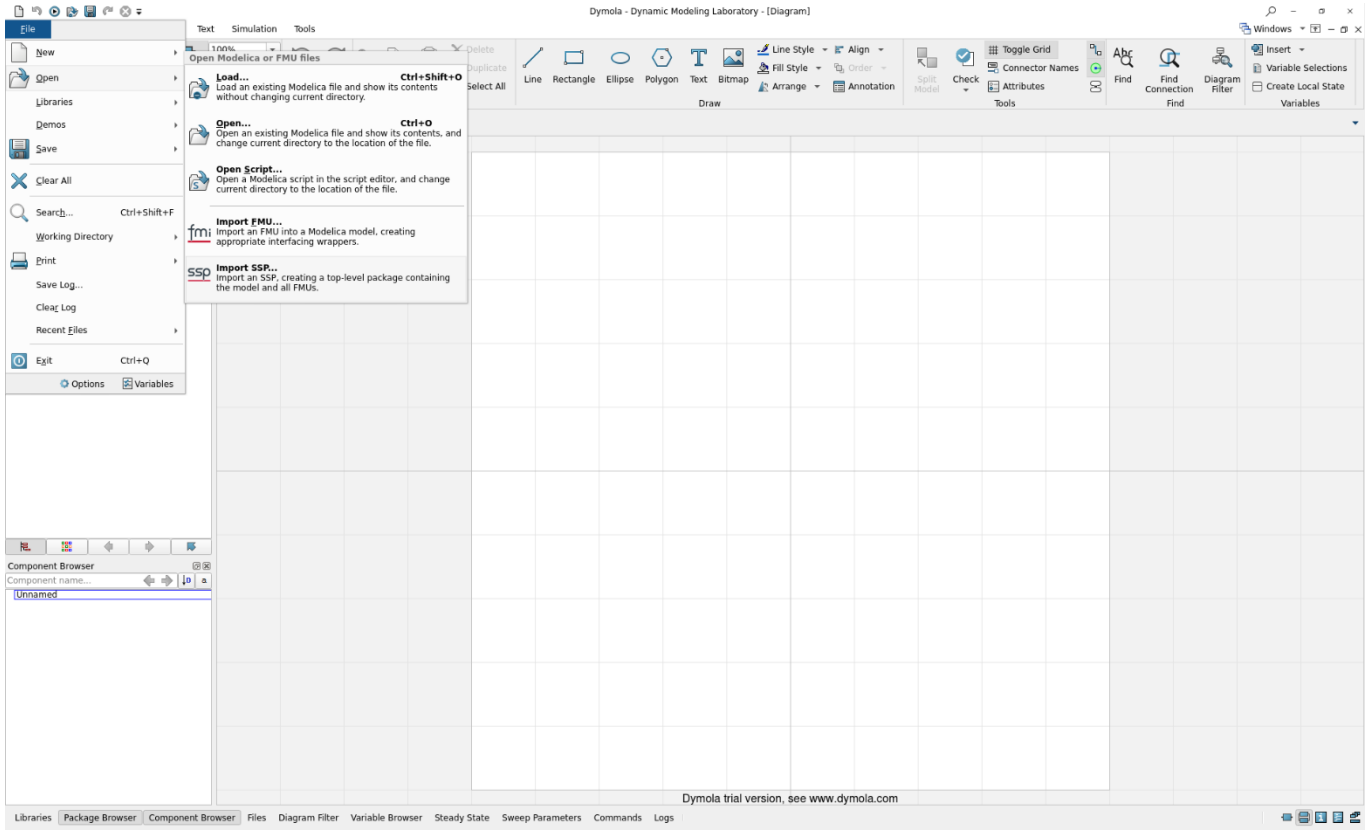

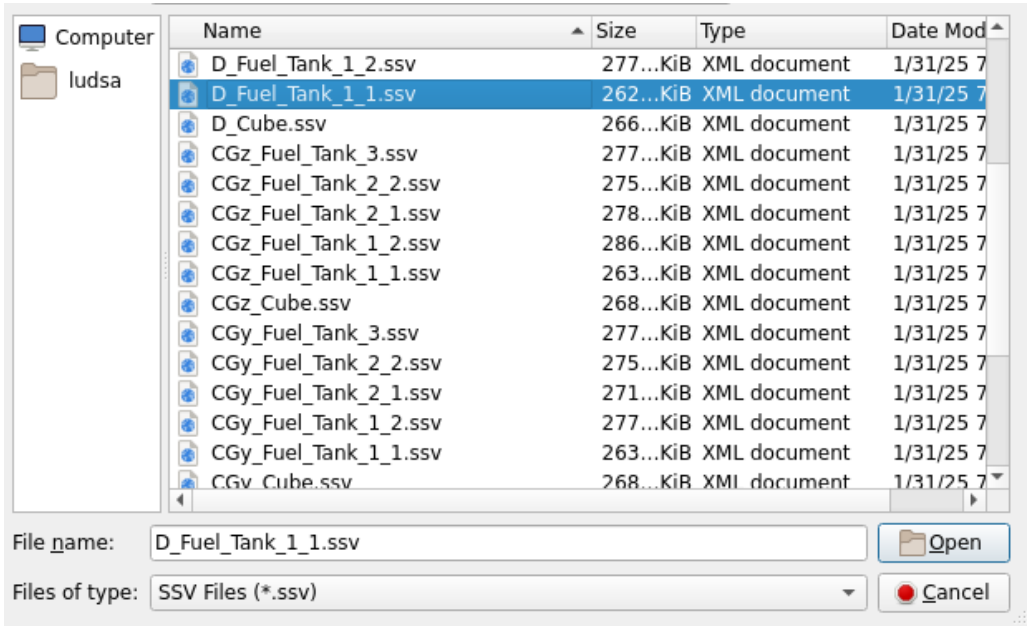

Conclusion and Future Work

- SSP standard
  - Enhances interoperability between different simulation tools (e.g., Modelica, Simulink, FMUs), making it easier to combine fuel system simulations with other physical models (thermal, structural, etc.)
  - Traceability
- SSP 2.0 Format
    - Easier to Read & Manage: Instead of having many separate entries, a single, structured entry is recieved
    - Reduces File Size & Redundancy: Instead of defining multiple similar parameters, they are stored in one array
    - Faster Data Processing: a single read operation can load all values instead of looping through multiple individual entries
- In the future, SSP 2.0 could enable standardization across industries and lead to seamless cross-platform engineering simulations, which means companies can share & reuse simulation models across different tools without compatibility issues
- ThermalFluidLibrary (work in Progress)

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