ETRI OMiLAB®

SAC 2025 - Programming Language

# A Platform-Independent Software-Intensive Workflow Modeling Language And An Open-Source Visual Programming Tool

## A Bottom-Up Approach Using Ontology Integration Of Industrial Workflow Engines

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# Outline

1. Introduction
2. Workflow modeling language and Tool
3. Evaluation
4. Conclusion

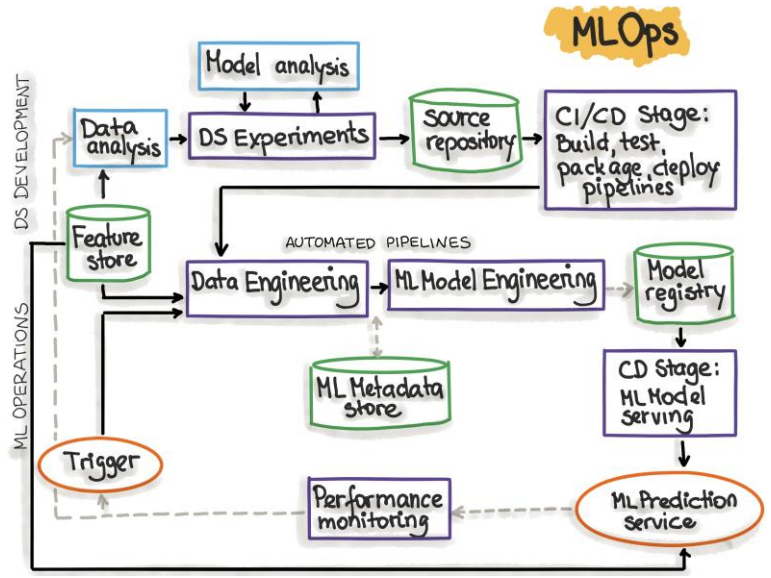
A Platform-Independent Software-Intensive Workflow Modeling Language And An Open-Source Visual Programming Tool

# Introduction

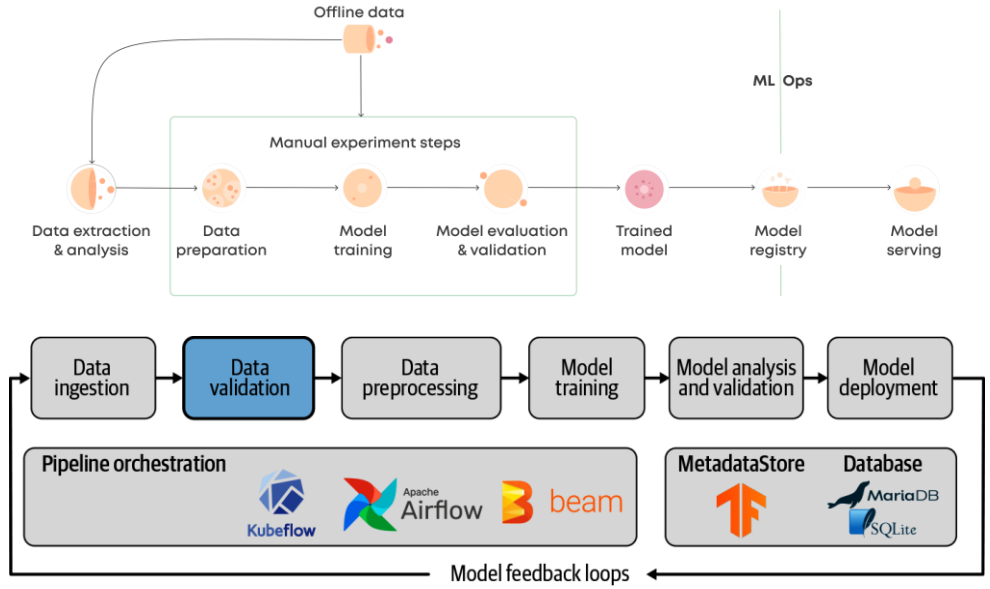
- Workflow engines and workflow software specifications
- Necessity of platform-independent visual language for workflow software

# Software-intensive Workflows

- Workflow is an effective tool to decompose and manage complex services (e.g., AI-enabled services, MLOps)
  - Automated execution, periodic execution, auto-repair, regular report, etc.



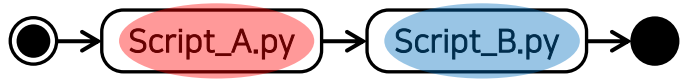

Cooperating tasks
using heterogeneous platforms, libraries, etc.




Orchestrating workflow of independent tasks

# Workflow Specification of Industrial Workflow Engines

- Many industrial platforms provides code-based specification and automated execution of workflow services based on their own grammars.




argo

```
apiVersion: argoproj.io/v1alpha1
kind: Workflow
metadata:
  generateName: sequential-pipeline-
spec:
  entrypoint: sequential-steps
  templates:
  - name: sequential-steps
    steps:
    - - name: step-a
        template: run-script
        arguments:
          parameters:
          - name: script
            value: "script_A.py"
    - - name: step-b
        template: run-script
        arguments:
          parameters:
          - name: script
            value: "script_B.py"

  - name: run-script
    inputs:
      parameters:
      - name: script
    container:
      image: python:3.9
      command: ["python"]
      args: ["{{inputs.parameters.script}}"]
```

Apache Airflow

```
from airflow import DAG
from airflow.operators.bash import BashOperat
or
from datetime import datetime

default_args = {
    'start_date': datetime(2024, 3, 11),
    'catchup': False
}

with DAG('sequential_workflow', default_args=
default_args, schedule_interval=None) as dag:

    step_a = BashOperator(
        task_id='run_script_A',
        bash_command='python script_A.py'
    )

    step_b = BashOperator(
        task_id='run_script_B',
        bash_command='python script_B.py'
    )

    step_a >> step_b  # Defines the execution
order
```

Kubeflow

```
from kfp import dsl

@dsl.pipeline(
    name='Sequential Workflow',
    description='A pipeline that runs two scr
ipts sequentially.'
)
def sequential_pipeline():
    step_a = dsl.ContainerOp(
        name='Run Script A',
        image='python:3.9',
        command=['python'],
        arguments=['script_A.py']
    )

    step_b = dsl.ContainerOp(
        name='Run Script B',
        image='python:3.9',
        command=['python'],
        arguments=['script_B.py']
    )

    step_a >> step_b  # Defines the execution
order

if __name__ == '__main__':
    import kfp.compiler as compiler
    compiler.Compiler().compile(sequential_pi
peline, 'sequential_pipeline.yaml')
```

METAFLOW

```
from metaflow import FlowSpec, step

class SequentialWorkflow(FlowSpec):

    @step
    def start(self):
        print("Running script_A.py")
        import os
        os.system("python script_A.py")
        self.next(self.step_b)

    @step
    def step_b(self):
        print("Running script_B.py")
        import os
        os.system("python script_B.py")
        self.next(self.end)

    @step
    def end(self):
        print("Workflow completed.")

if __name__ == "__main__":
    SequentialWorkflow()
```

# Necessity of Platform-independent WorkflowML

- Challenges
  - Inefficient code-based workflow specification (e.g., hundreds of lines)
    - Error-prone process and poor communicability
  - Platform-independent grammars
    - Difficult platform migration despite common semantics

- Goal
  - Platform-independent and visual **language** for workflow specification
  - Open-source workflow modeling **tool**

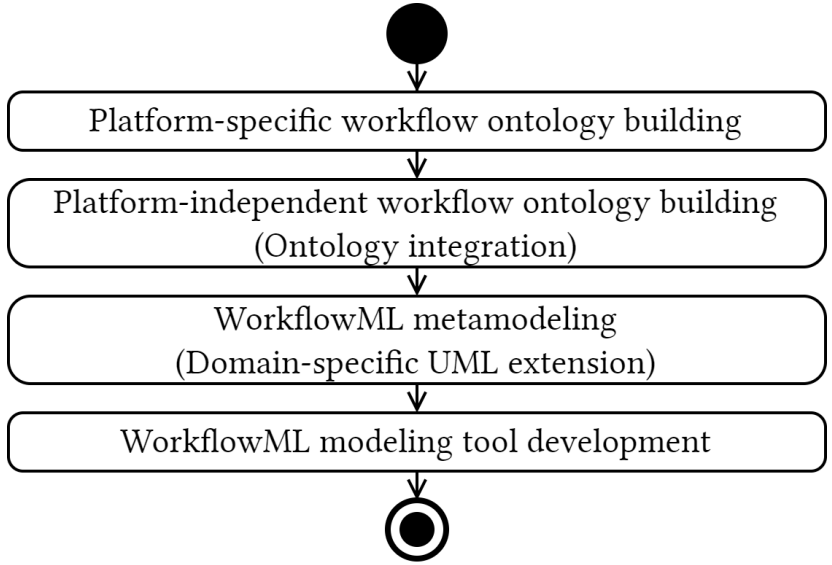
A Platform-Independent Software-Intensive Workflow Modeling Language And An Open-Source Visual Programming Tool

# Workflow modeling language (WorkflowML) and Tool

- WorkflowML metamodeling
- WorkflowML tool development on ADOxx

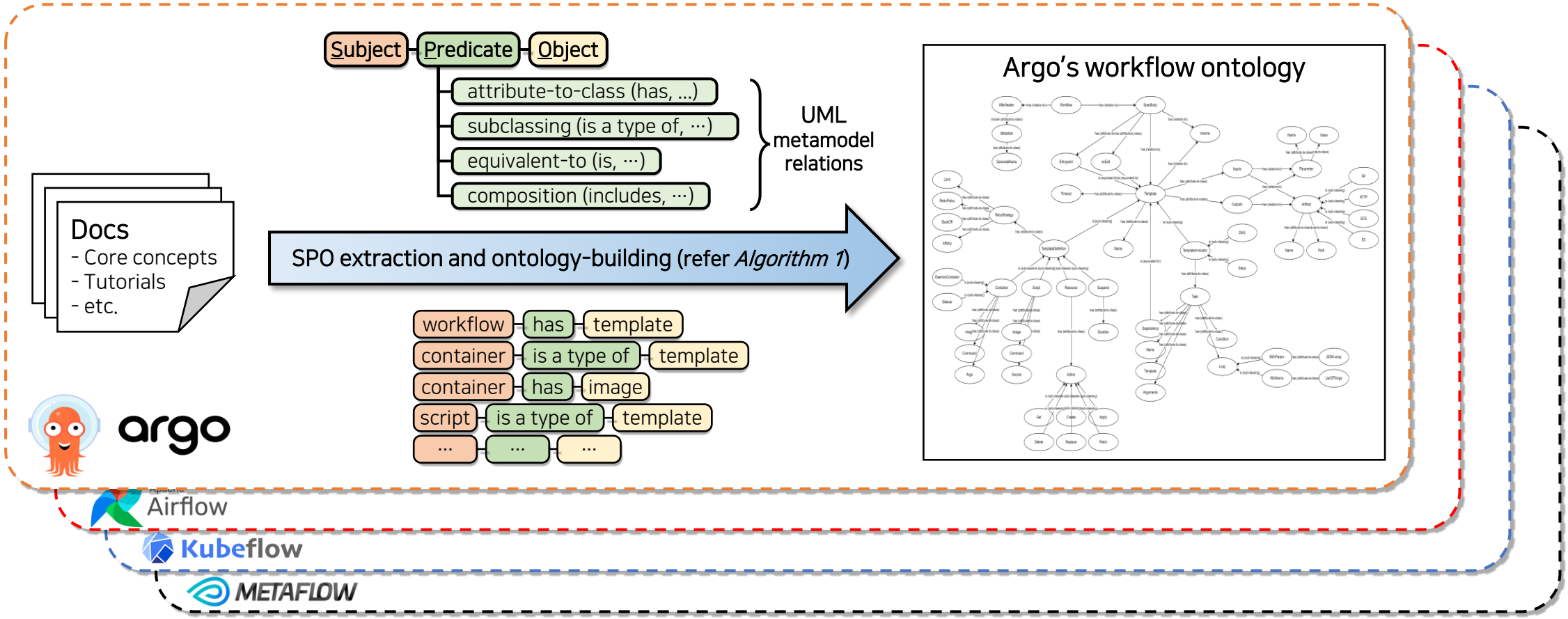
# Overall Approach

- Bottom-up WorkflowML development
  - Collect workflow concepts from platforms
  - Integrate workflow concepts
  - Develop WorkflowML extending UML activity diagram
- ADOxx-powered visual programming tool
  - https://adoxx.org/
  - Open-use metamodeling platform of OMiLAB NPO
  - Easy development and deployment of domain-specific modeling language



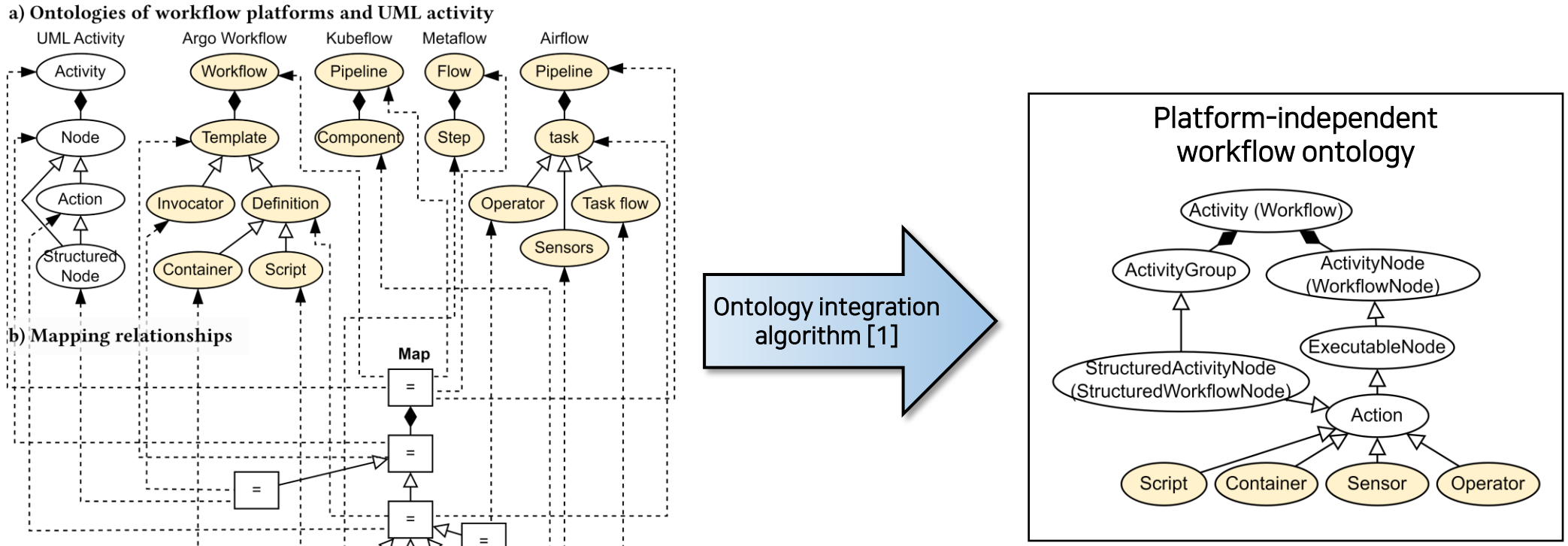
# Platform-specific Ontology Building

- Collect ontologies (graphs) from independent workflow platforms.



# Platform-Independent Ontology Building (1/2)

- Integrate ontologies of platform-specific workflows and UML activity

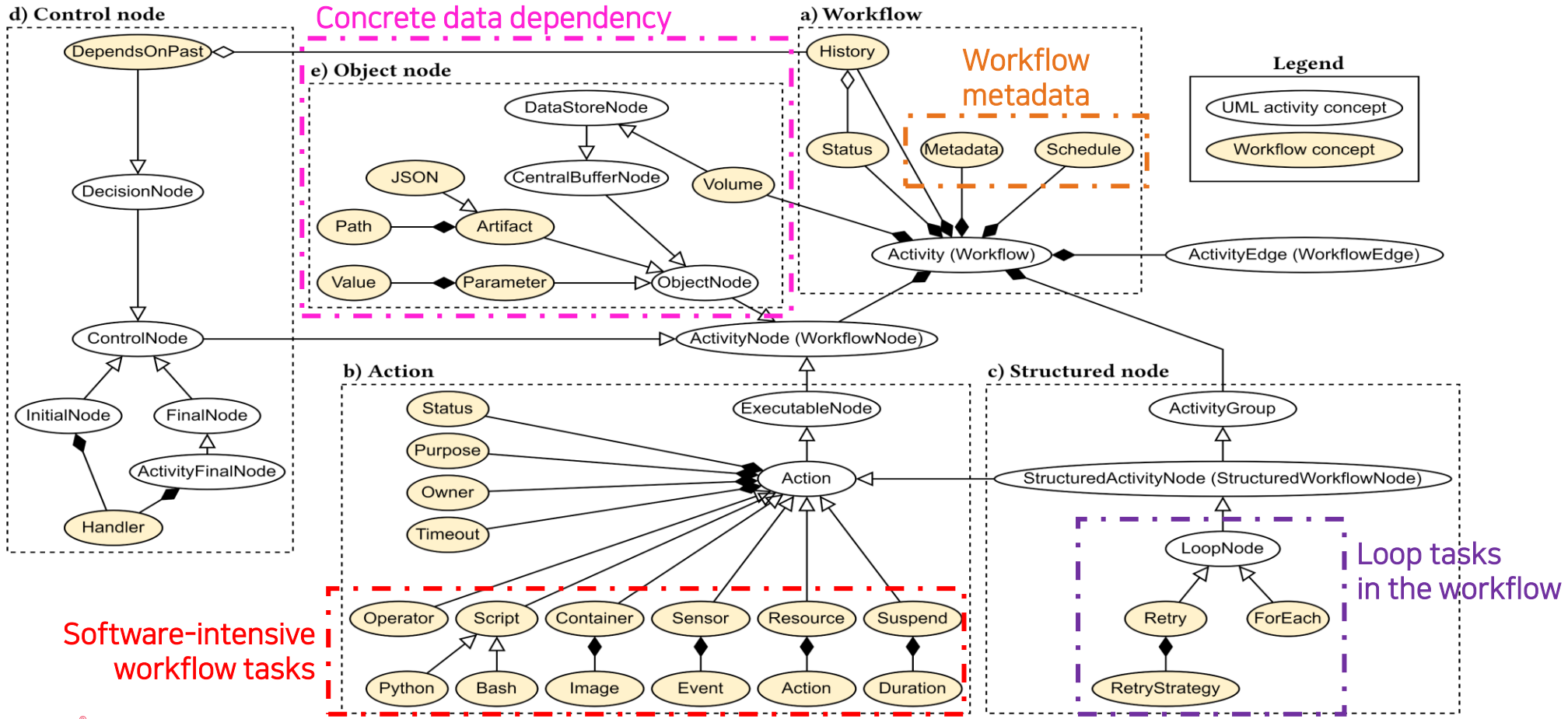





[1] Rachel A Pottinger and Philip A Bernstein. 2003. Merging models based on given correspondences. In Proceedings 2003 VLDB Conference. Elsevier, 862–873.

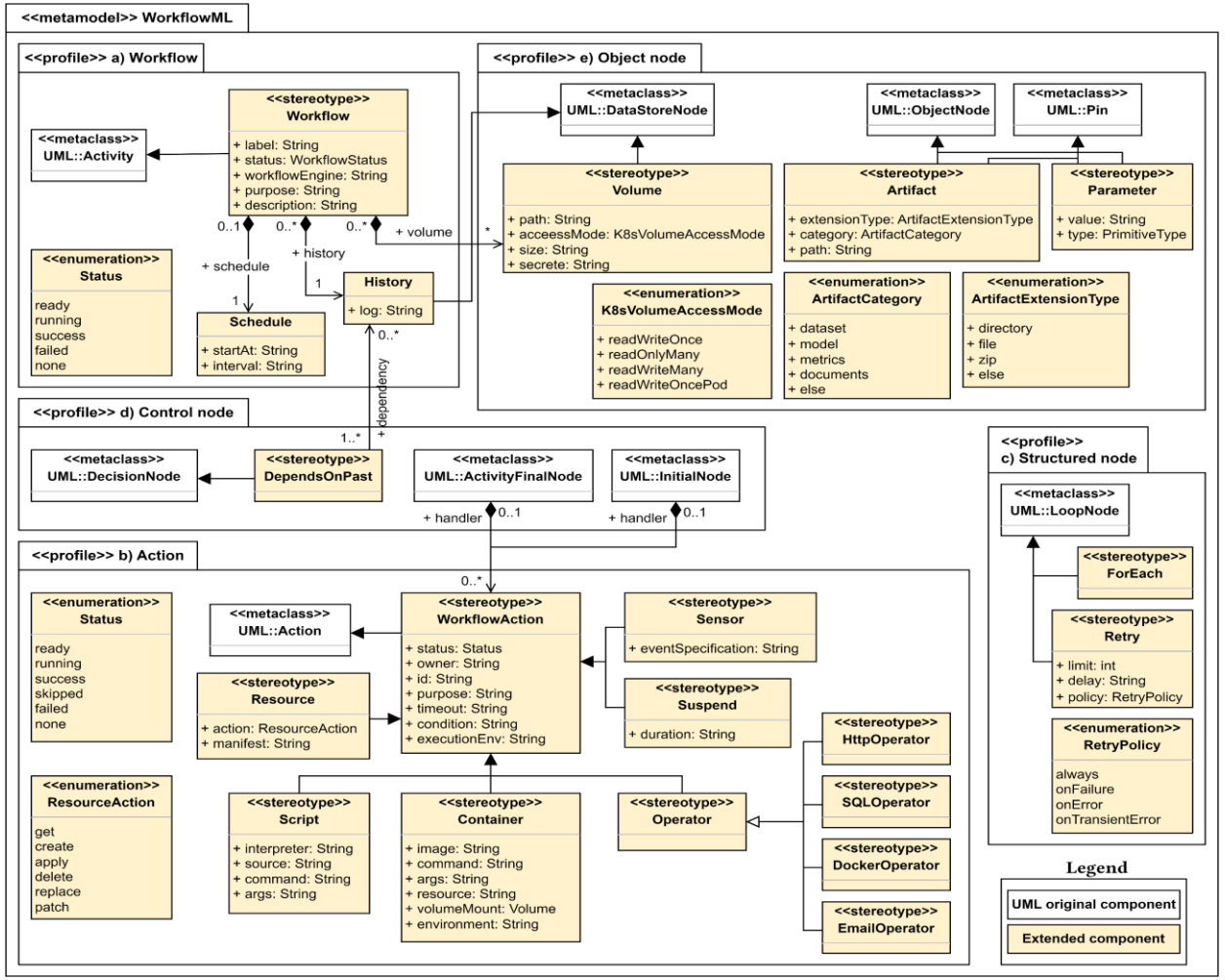
# Platform-Independent Ontology Building (2/2)

- A snippet of integrated ontologies of the workflow platforms and the UML



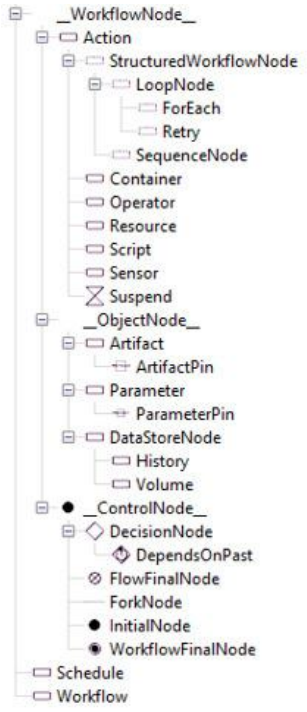
# WorkflowML Metamodeling

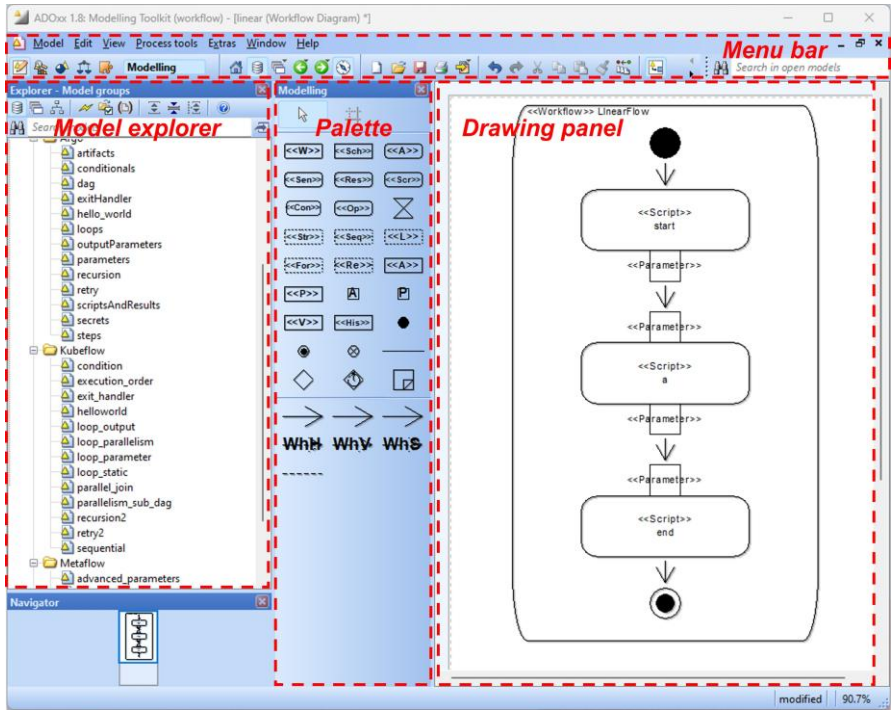
- Extend the metamodel of UML activity diagram based on the integrated workflow ontology
  - Defining stereotypes
  - Connecting the stereotypes to metaclasses
  - Defining attributes and enumerations

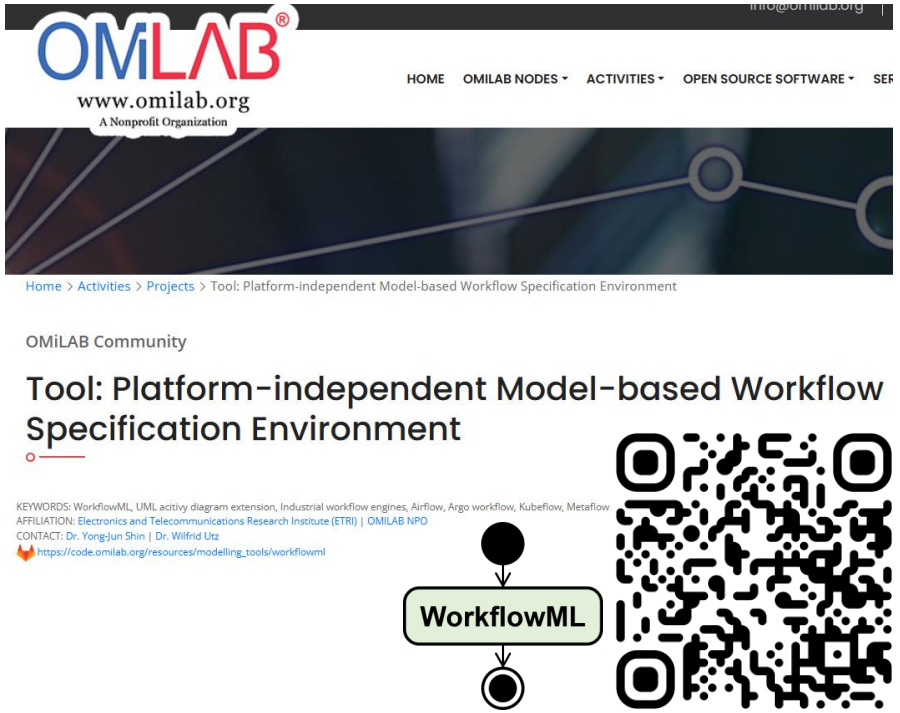


# WorkflowML (Tool) Development On ADOxx

- Develop WorkflowML and its tool on ADOxx with graphical notations
  - The tool and source are available at https://www.omilab.org/workflowml/



# Evaluation

- Expressiveness of the WorkflowML
- Real case studies

# Software-Intensive Workflow Concept Representation

- WorkflowML improves expressiveness of UML activity diagram for software-intensive workflow specification.
  - 22 new components for workflow

| WorkflowML component | # |
|---|---|
| Reused (UML activity components) | 33 |
| Extended (Domain-specific components) | 22 |
| Total | 55 |

**Table 2: Summary of the number of WorkflowML components**

| Domain-specific concept | UML | BPML | YAWL | WorkflowML |
|---|---|---|---|---|
| 1. Workflow execution schedule | X | △ (Timer) | △ (Time task) | O (Schedule) |
| 2. Workflow execution history | X | X | X | O (History) |
| 3. Conditional execution of actions depending on the past execution | X | X | X | O (DependsOnPast) |
| 4. Workflow data directory | △ (Central buffer) | △ (Data store) | X | O (Volulme) |
| 5. Parallel task execution for iterable items | △ (Loop) | O (Multiple instance task) | O (Multiple instance task) | O (ForEach) |
| 6. Retry of failed workflow tasks | △ (Loop) | △ (Loop) | △ (Loop) | O (Retry) |
| 7. Domain-specific types of workflow tasks | △ (Action, etc.) | △ (Send, Recieve, Manual, etc.) | △ (Task, etc.) | O (Container, Script, etc.) |

**Table 3: Domain-specific concept expressiveness of WorkflowML and domain-general process modeling languages. O/△/X indicates that the concept is explicitly, indirectly, or not expressible, respectively, by the language.**

# Expressiveness Evaluation of the WorkflowML

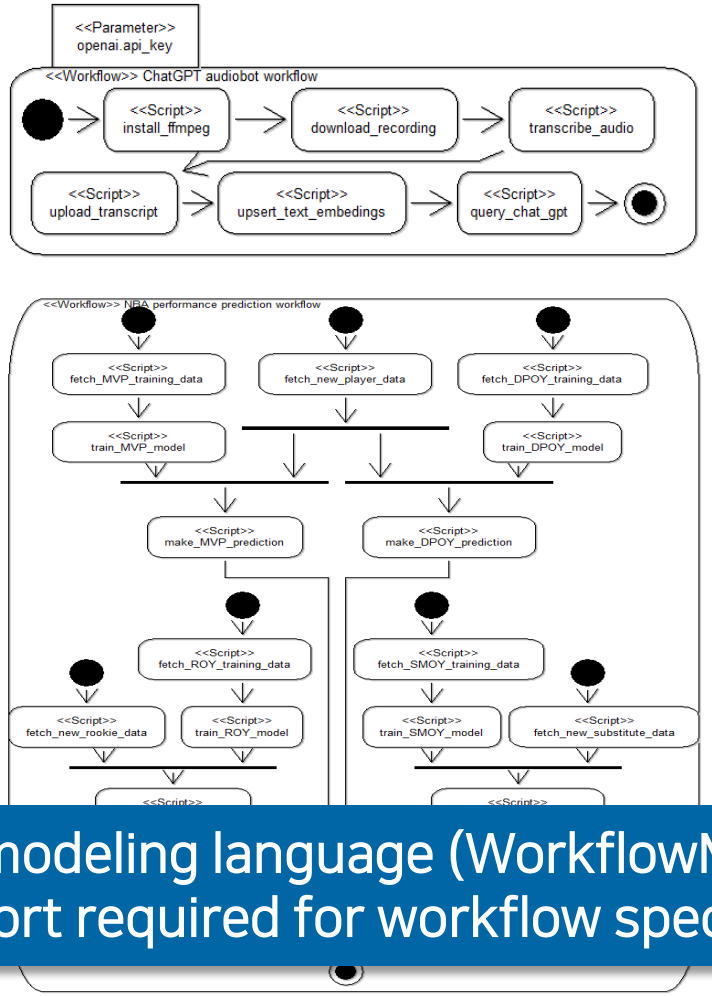
- Visual programming coverage (%)
  - The ratio of visual-programmable workflow specifications to platform-specific code-based specifications
- WorkflowML achieved an average VP coverage of 90%
  - across 42 example workflows from the four target workflow platforms

| Workflow platform | Example workflow name | LoC of workflow Total (a) | LoC of workflow Modeled (b) | Visual programming coverage (b/a)(%) | Average |
|---|---|---|---|---|---|
| Airflow | Example_nested_branch_dag | 56 | 47 | 83.93% | 87.65% |
| | Example_task_group | 64 | 55 | 85.94% | |
| | Example_bash_operator | 76 | 66 | 86.84% | |
| | Tutorial_taskflow_api_virtualenv | 87 | 74 | 85.06% | |
| | Example_branch_datetime_operator | 104 | 95 | 91.35% | |
| | Example_sensors | 123 | 106 | 86.18% | |
| | Tutorial_taskflow_api | 107 | 94 | 87.85% | |
| | Tutorial | 125 | 107 | 85.60% | |
| | Tutorial_dag | 135 | 118 | 87.41% | |
| | Example_complex | 220 | 212 | 96.36% | |
| Argo workflow | Hello_world | 16 | 16 | 100.00% | 96.20% |
| | Retrying_failed_or_errored_steps | 23 | 19 | 82.61% | |
| | Parameters | 26 | 26 | 100.00% | |
| | Recursion | 34 | 34 | 100.00% | |
| | Secrets | 34 | 34 | 100.00% | |
| | Scripts_and_results | 50 | 34 | 68.00% | |
| | DAG | 36 | 36 | 100.00% | |
| | Output_parameters | 38 | 38 | 100.00% | |
| | Steps | 41 | 41 | 100.00% | |
| | Artifacts | 43 | 43 | 100.00% | |
| | Exit_handler | 44 | 44 | 100.00% | |
| | Loops | 49 | 49 | 100.00% | |
| | Conditionals | 64 | 64 | 100.00% | |
| Kubeflow pipeline | Loop_static | 26 | 24 | 92.31% | 89.41% |
| | Loop_parameter | 27 | 25 | 92.59% | |
| | Hello_world | 30 | 26 | 86.67% | |
| | Loop_parallelism | 30 | 27 | 90.00% | |
| | Loop_output | 30 | 28 | 93.33% | |
| | Execution_order | 38 | 34 | 89.47% | |
| | Retry | 39 | 35 | 89.74% | |
| | Condition | 46 | 41 | 89.13% | |
| | Exit_handler | 50 | 46 | 92.00% | |
| | Parallel_join | 53 | 50 | 94.34% | |
| Metaflow | Parameters | 18 | 15 | 83.33% | 90.48% |
| | Linear | 20 | 17 | 85.00% | |
| | Advanced_parameters | 23 | 20 | 86.96% | |
| | Foreach | 27 | 24 | 88.89% | |
| | Branch | 31 | 28 | 90.32% | |
| | Parallelism_sub_dag | 34 | 30 | 88.24% | |
| | Sequential | 48 | 45 | 93.75% | |
| | Data_flow | 60 | 57 | 95.00% | |
| | Recursion | 69 | 66 | 95.65% | |

**Table 4: Expressiveness evaluation results of the workflow specification of WorkflowML**

# Real Case Applications of the WorkflowML

- ChatGPT audiobot workflow [1]
  - VP coverage: **92.77%**
    - Total LoC: 249 lines
- NBA performance prediction workflow [2]
  - VP coverage: **95.2%**
    - Total LoC: 459 lines




**Our platform-independent workflow modeling language (WorkflowML) significantly reduces the complexity and effort required for workflow specification.**

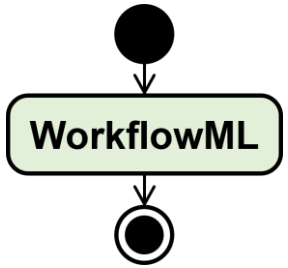


[1] https://github.com/anujkumar98/Meeting-Intelligence-Application/blob/main/Airflow/dag.py
[2] https://github.com/Sapphirine/202212-19-NBA-Player-Awards-and-Team-Performance-Prediction/blob/main/Player_DAG.py

# Conclusion

# Contributions

- A reusable bottom-up method for developing domain-specific modeling language using ontology integration
  - Ontology building, ontology integration, and metamodeling algorithms
- Platform-independent WoflowML based on ontologies
  - Ontology building data
  - Metamodels
- An open source WorkflowML tool
  - WorkflowML and its graphical notation implementation sources
  - 42 simple example workflow models
  - 2 real-case workflow models



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# Thank you

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