Performance Metrics and Ontology for Describing Performance Data of Grid Workflows

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Outline

- Motivation
- Grid workflows and workflow execution model
- Performance metrics of Grid workflows
- WfPerfOnto: Ontology for describing performance data of Grid workflows
- Utilizing WfPerfOnto
- Conclusion and Future work

Motivation

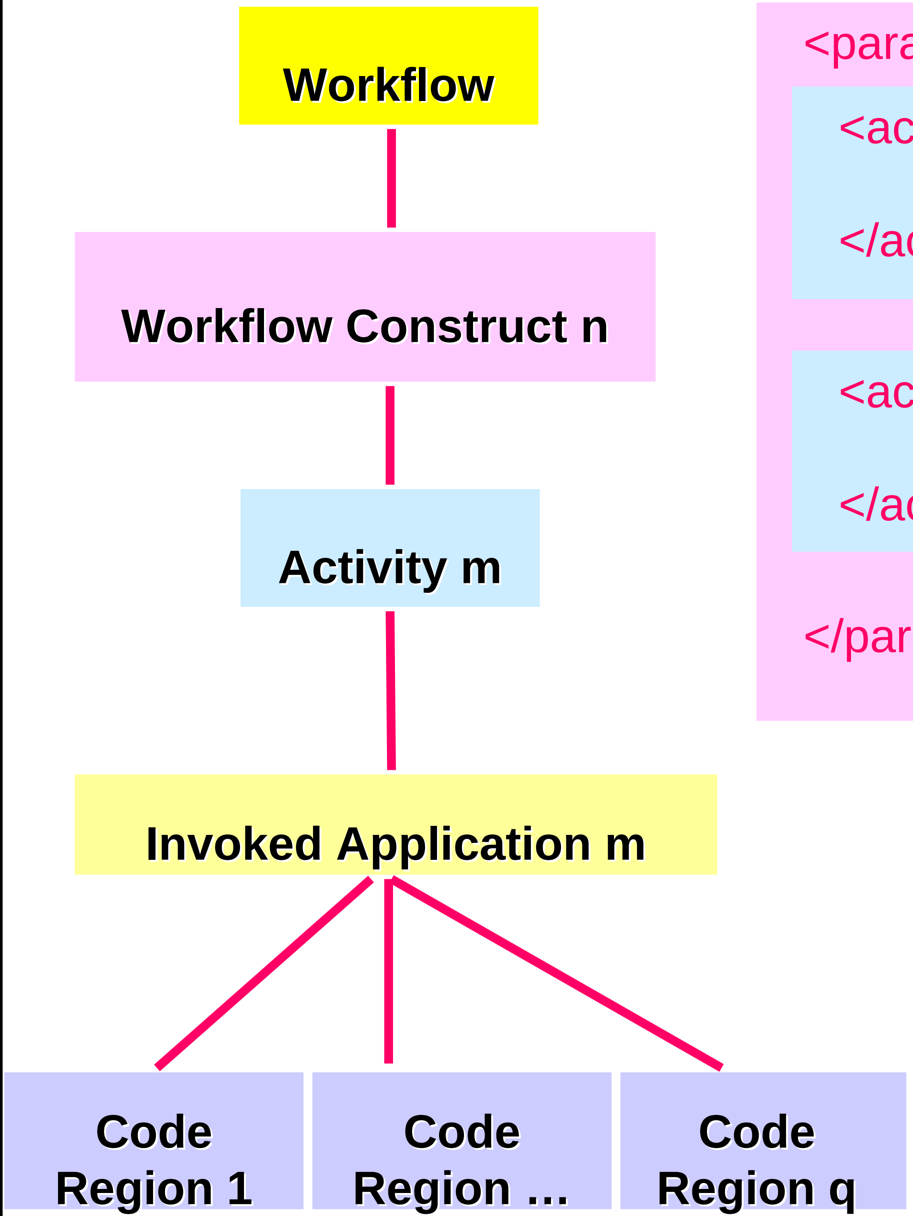
- Lack of comprehensive study of useful performance metrics for Grid workflows
  - A few metrics are studied and supported
  - Most of metrics are being limited to the activity (task) level.

  study performance metrics at multiple levels of abstraction

- Describing and sharing performance data of Grid workflows
  - Highly heterogeneous, inter-related and dynamic
  - Inter-organizational
  - Multiple types of performance and monitoring data provided by various tools

  an ontology for performance data
    - Can be used to describe concepts associated with workflow executions
    - Will facilitate the performance data sharing

Hierarchical Structure View of a Workflow



```
<parallel>
  <activity name="mProject2">
        <executable name="/home/truong/mProject2"/>
  </activity>

  <activity name="mProject1">
        <executable name="/home/truong/mProject1"/>
  </activity>

</parallel>
```

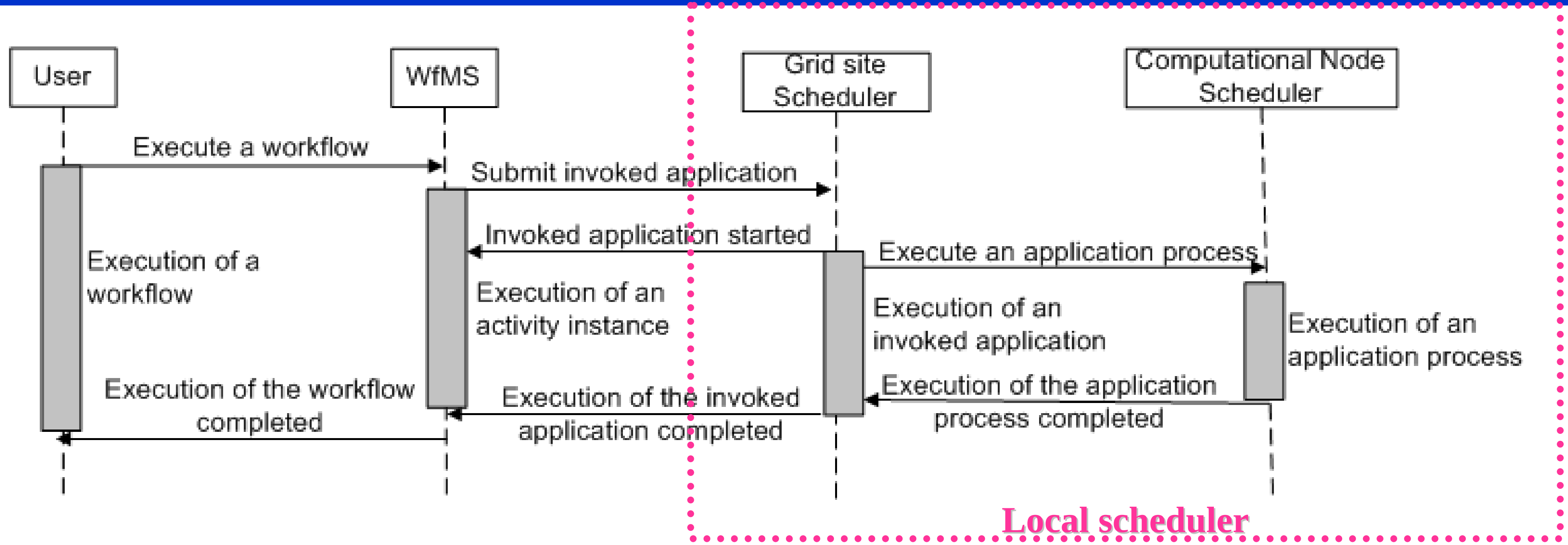
```
mProject1.c
      int main() {

                  A();

                  while () {
                  …
                   }

      }
```

Workflow Execution Model (Simplified)



User
WfMS
Grid site Scheduler
Computational Node Scheduler
Execute a workflow
Submit invoked application
Invoked application started
Execute an application process
Execution of a workflow
Execution of an activity instance
Execution of an invoked application
Execution of an application process
Execution of the workflow completed
Execution of the invoked application completed
Execution of the application process completed
Local scheduler

- Workflow execution
  - Spanning multiple Grid sites
  - Highly inter-organizational, inter-related and dynamic
- Multiple levels of job scheduling
  - At workflow execution engine (part of WfMS)
  - At Grid sites

Performance Metrics of Grid Workflows

- Interesting performance metrics associated with multiple levels of abstraction
  - Metrics can be used in workflow composition, for comparing different invoked applications of a single activity, etc.
- Five levels of abstraction
  - Code region, Invoked application
  - Activity,Workflow construct, Workflow
- Performance metrics of a lower level can be used to construct similar metrics for the immediate higher-level
  - By using aggregate operator
  - Based on metric definition and structure of workflows

Performance Metrics at Code Region Level

Category	Metric
Execution time	ElapsedTIme, UserCPUTime, SystemCPUTime, SerialTime, EncodingTime
Counter	L2_TCM, L2_TCA, etc., (hardware counters)
	NCalls, NSubs, RecvMsgCount, SendMsgCount
Synchronization	CondSynTime, ExclSynTime
Data Movement	TotalCommTime, TotalTransSize
Ratio	MeanElapsedTime, CommPerComp, MeanTransRate, MeanTranSize
	CachMissRatio, MFLOPS, etc.
Temporal overhead	temporal overhead of parallel code regions

- Most existing conventional performance tools provide these metrics
- Existing workflow monitoring and analysis tools normally do not
- Challenging issues
  - Integrate conventional performance monitoring tools into workflow monitoring tools

Performance Metrics at Invoked Application Level

- Most metrics can be constructed from metrics at code region level

Category	Metric
Execution time	ElapsedTime
	FailedTime
Counter	NCallFailed
	NCalls
Ratio	FailedFreq
Performance Improvement	SpeedupFactor

Performance Metrics at Activity Level

Category	Metric
Execution time	ElapsedTime, ProcessingTime, QueuingTime, SuspendingTime
	FailedTime, SharedResTime
Counter	RedandantActivity, NIteration, PathSelectionRatio, ResUtilization
Ratio	Throughput, MeanTimePerState, TransRate
Synchronization	SynDelay, ExecDelay
Performance Improvement	SlowdownFactor

- Metrics can be defined for both activity and activity instance
- Aggregate metrics of an activity can be defined based on its instances and the execution of instances at runtime
- Challenging problems
    - How to monitor and correlate metrics when a resource is shared among applications

Performance Metrics at Workflow Construct Level

Category	Metric
Execution time	ElapsedTime, ProcessingTime
Counter	RedandantActivity,
	NIteration, PathSelectionRatio, ResUtilization
Load balancing	LoadIm (Load imbalance)
Performance Improvement	SpeedupFactor
Resource	RedundantProcessing

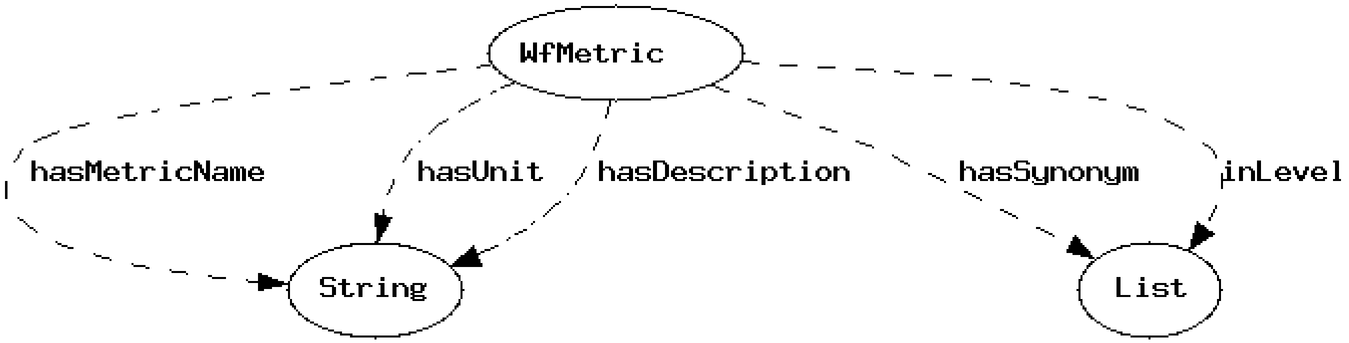
- Aggregate metrics of a workflow construct/workflow construct instance are defined based on the structure of the construct. E.g.,
  - LoadIm (load imbalance) is for parallel construct
  - ElapsedTime/ProcessingTime is defined based on critical path

Performance Metrics at Workflow Level

Category	Metric
Execution time	ElapsedTime,ProcesingTime
	ParTime,SeqTime
Ratio	QueuingRatio, MeanProcessingTime, MeanQueuingTime, ResUtilization
Correlation	NAPerRes,ProcInRes,LoadImRes
Performance Improvement	Speedup

Performance Metrics Ontology

- WfMetricOnto
  - OWL-based performance metrics ontology



- Metrics ontology
  - Specifies which performance metrics a tool can provide
  - Simplifies the access to performance metrics provided by various tools

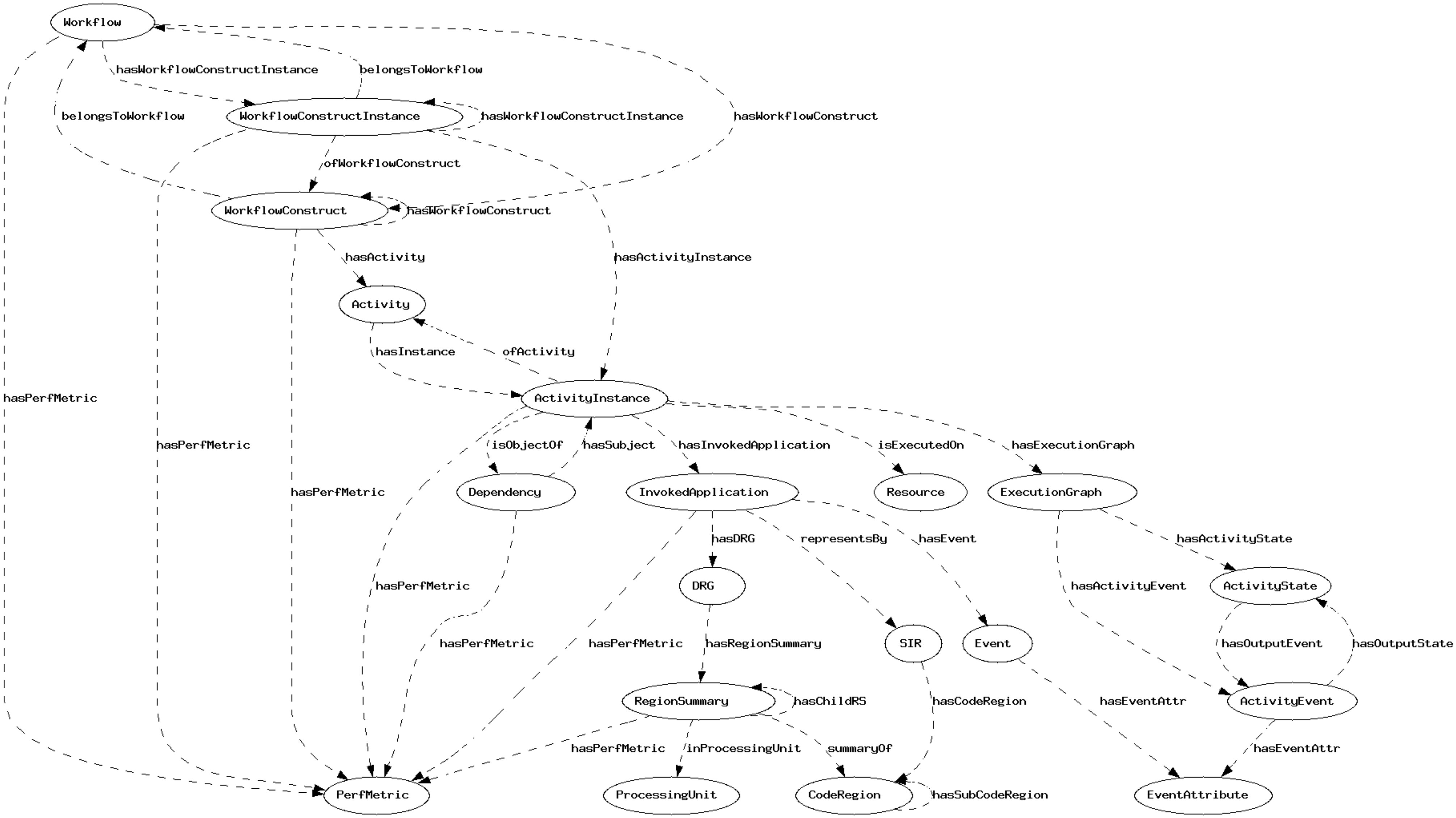
Monitoring and Measuring Performance Metrics

- Performance monitoring and analysis tools
  - Operate at multiple levels
  - Correlate performance metrics from multiple levels
- Middleware and application instrumentation
  - Instrument execution engine of WfMS
    - Execution engine can be distributed or centralized
  - Instrument applications
    - Distributed, spanning multiple Grid sites
- Challenging problems: Performance tool and data complexity
  - Integrate multiple performance monitoring tools executed on multiple Grid sites
  - Integrate performance data produced by various tools

Ontology Describing Performance Data of Grid Workflows

- Objectives
  - Understanding basic concepts associated with performance data of Grid workflows
  - Performance data integration for Grid workflows
  - Towards distributed/intelligent performance analysis
- WfPerfOnto (Ontology describing Performance data of Grid Workflows)
  - Basic concepts
    - Concepts reflects the hierarchical view of a workflow
    - Static and dynamic performance and monitoring data of workflow
  - Relationships
    - Static and dynamic relationships among concepts

Ontology for Describing Performance Data of Grid Workflows

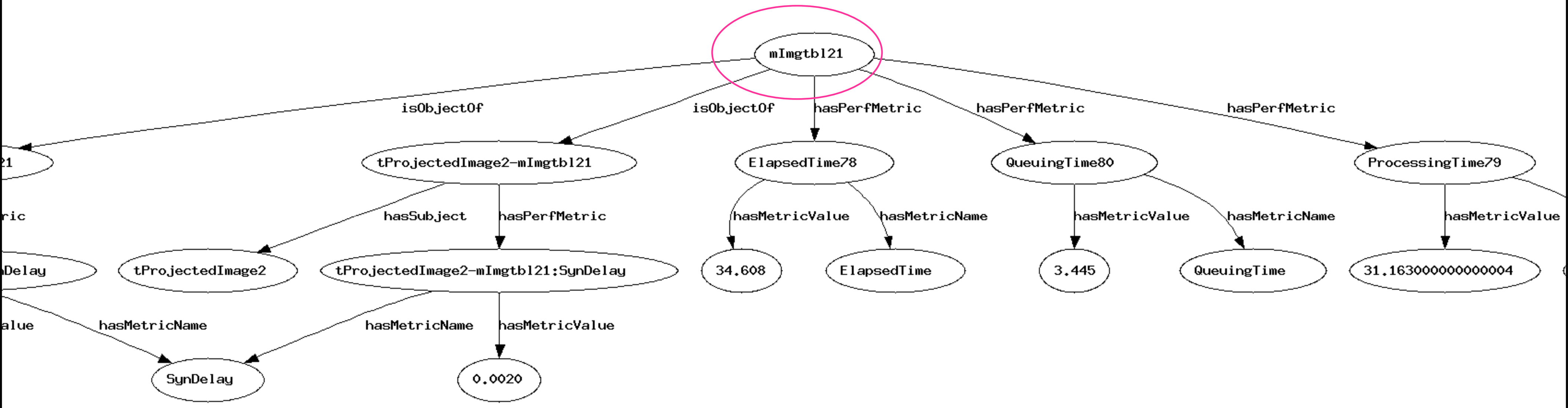


Utilizing WfPerfOnto

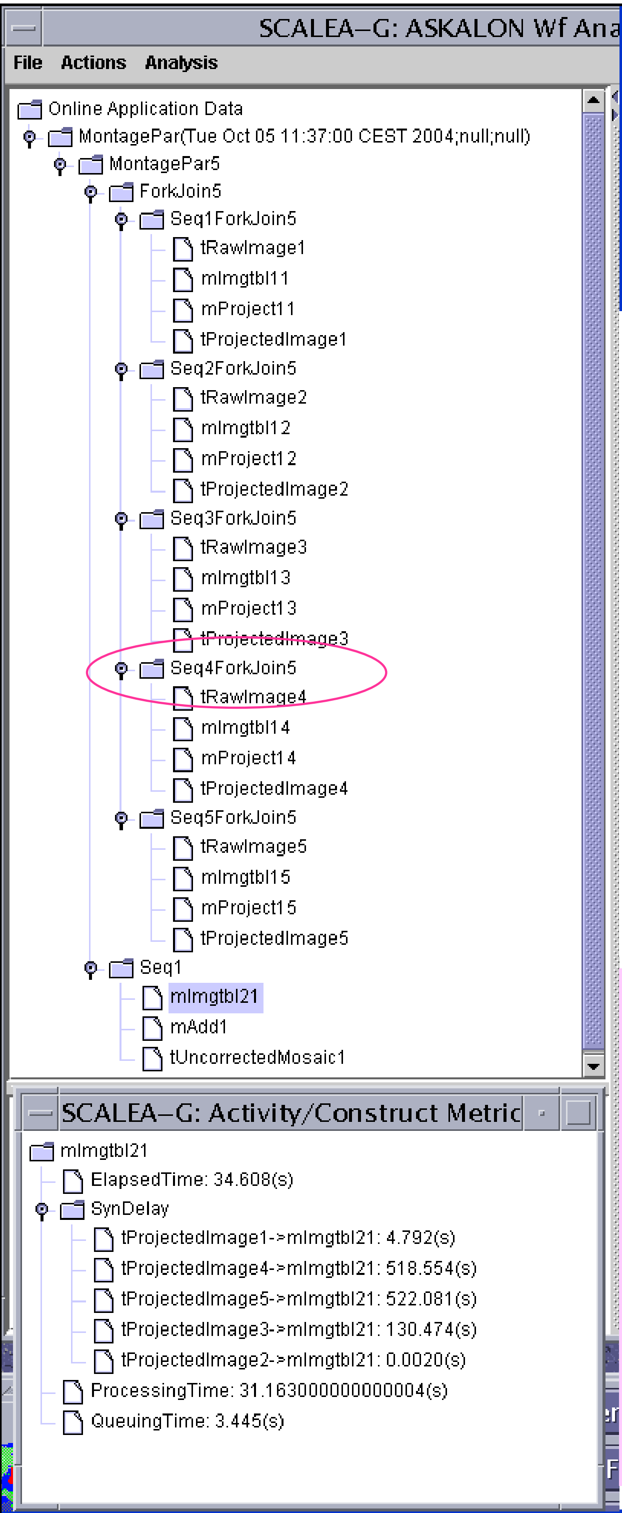
- Describing Performance Data and Data Integration
  - Different monitoring and analysis tools can store/export performance data in/to ontological representation
  - High-level search and retrieval of performance data
- Knowledge base performance data of Grid workflows
  - Utilized by high-level tools such as schedulers, workflow composition tools, etc.
  - Used to re(discover) workflow patterns, interactions in workflows, to check correct execution, etc.
- Distributed Performance Analysis
  - Performance analysis requests can be built based on WfPerfOnto

Utilizing WfPerfOnto: Describing Performance Data

```
<rdf:Description rdf:about="http://dps.uibk.ac.at/wfperfonto#mImgtbl21">
   <wfperfonto:hasPerfMetric rdf:resource="http://dps.uibk.ac.at/wfperfonto#ElapsedTime78"/>
   <rdf:type rdf:resource="http://dps.uibk.ac.at/wfperfonto#ActivityInstance"/>
   <wfperfonto:instanceName>mImgtbl21</wfperfonto:instanceName>
   <wfperfonto:hasPerfMetric rdf:resource="http://dps.uibk.ac.at/wfperfonto#QueuingTime80"/>
   <wfperfonto:ofActivity rdf:resource="http://dps.uibk.ac.at/wfperfonto#mImgtbl2"/>
   <wfperfonto:hasPerfMetric rdf:resource="http://dps.uibk.ac.at/wfperfonto#ProcessingTime79"/>
  </rdf:Description>
```



Utilizing WfPerfOnto: Checking Correct Execution

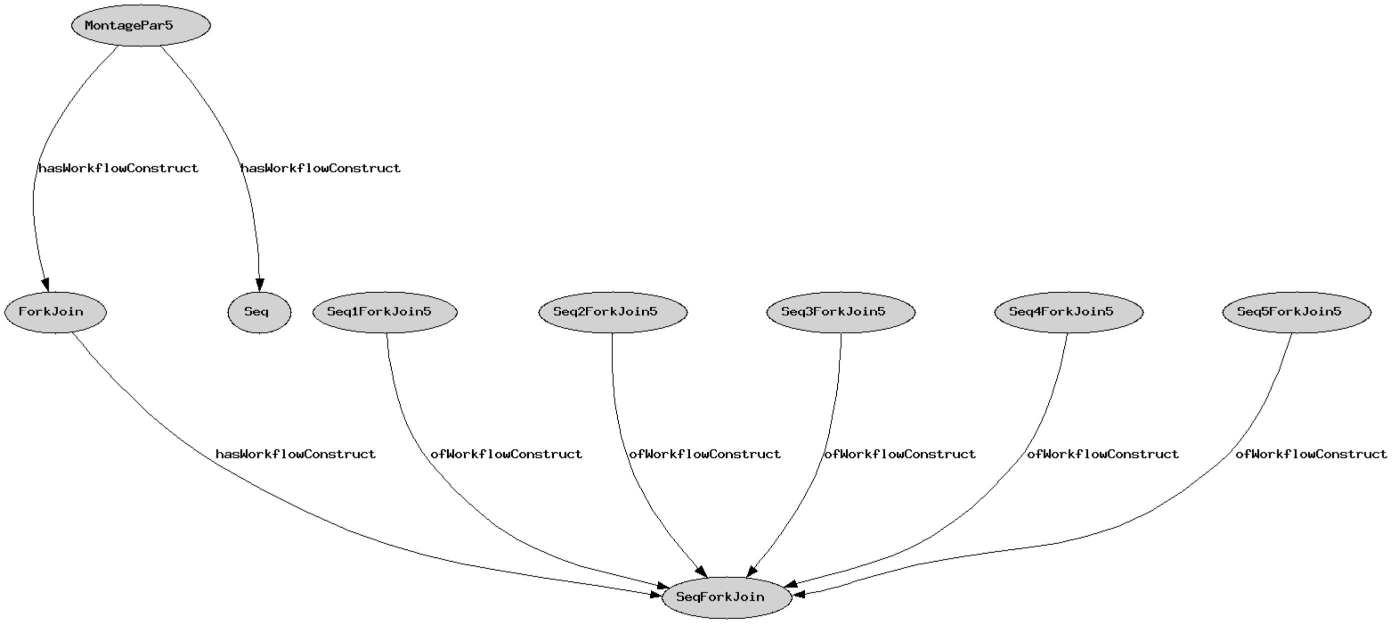


```
SCALEA-G: ASKALON Wf Ana
File   Actions   Analysis

Online Application Data
  MontagePar(Tue Oct 05 11:37:00 CEST 2004;null;null)
    MontagePar5
      ForkJoin5
        Seq1ForkJoin5
          tRawImage1
          mImgtbl11
          mProject11
          tProjectedImage1
        Seq2ForkJoin5
          tRawImage2
          mImgtbl12
          mProject12
          tProjectedImage2
        Seq3ForkJoin5
          tRawImage3
          mImgtbl13
          mProject13
          tProjectedImage3
        Seq4ForkJoin5
          tRawImage4
          mImgtbl14
          mProject14
          tProjectedImage4
        Seq5ForkJoin5
          tRawImage5
          mImgtbl15
          mProject15
          tProjectedImage5
      Seq1
        mImgtbl21
        mAdd1
        tUncorrectedMosaic1
```

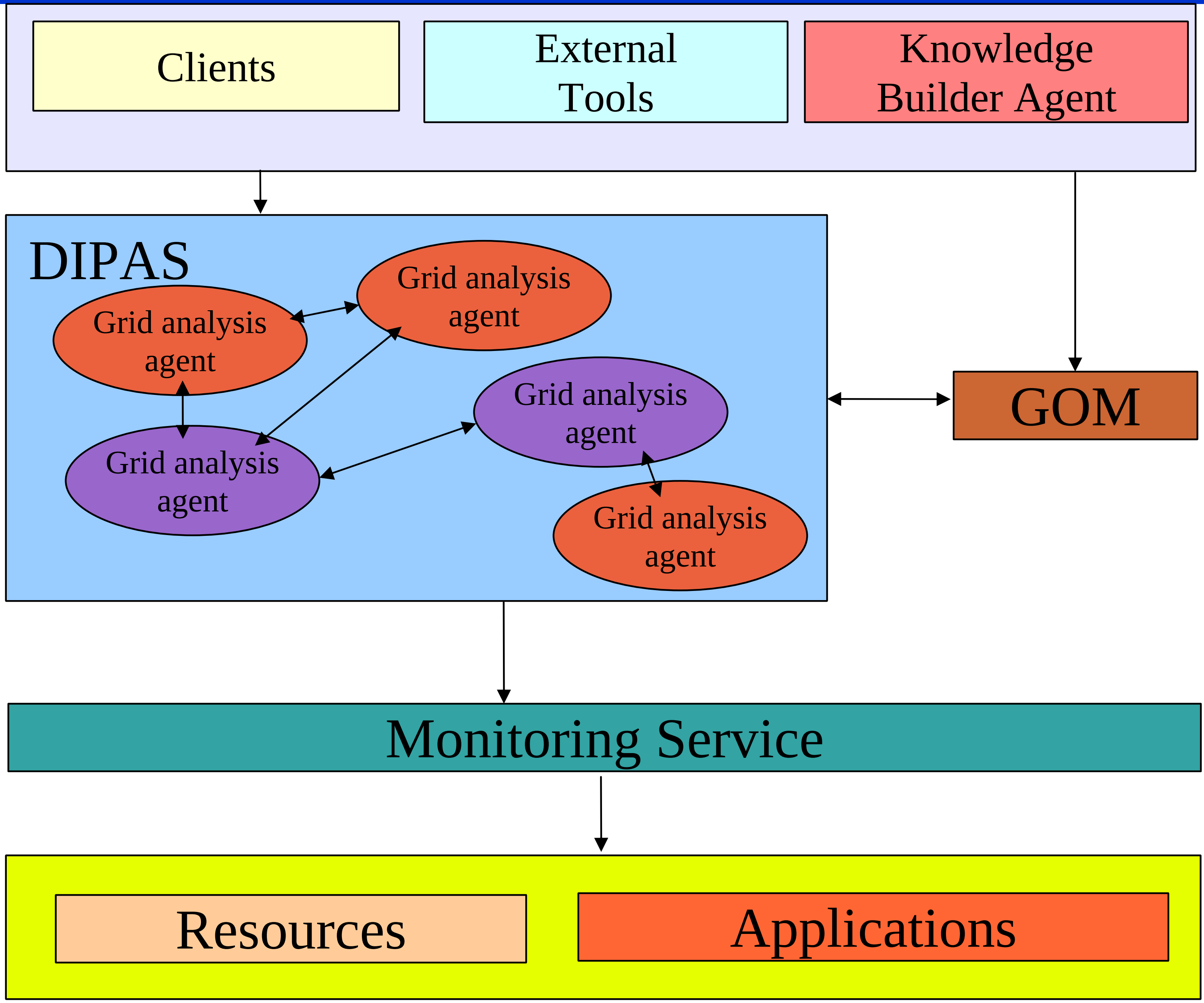
```
SCALEA-G: Activity/Construct Metric

mImgtbl21
  ElapsedTime: 34.608(s)
  SynDelay
    tProjectedImage1->mImgtbl21: 4.792(s)
    tProjectedImage4->mImgtbl21: 518.554(s)
    tProjectedImage5->mImgtbl21: 522.081(s)
    tProjectedImage3->mImgtbl21: 130.474(s)
    tProjectedImage2->mImgtbl21: 0.0020(s)
  ProcessingTime: 31.163000000000004(s)
  QueuingTime: 3.445(s)
```

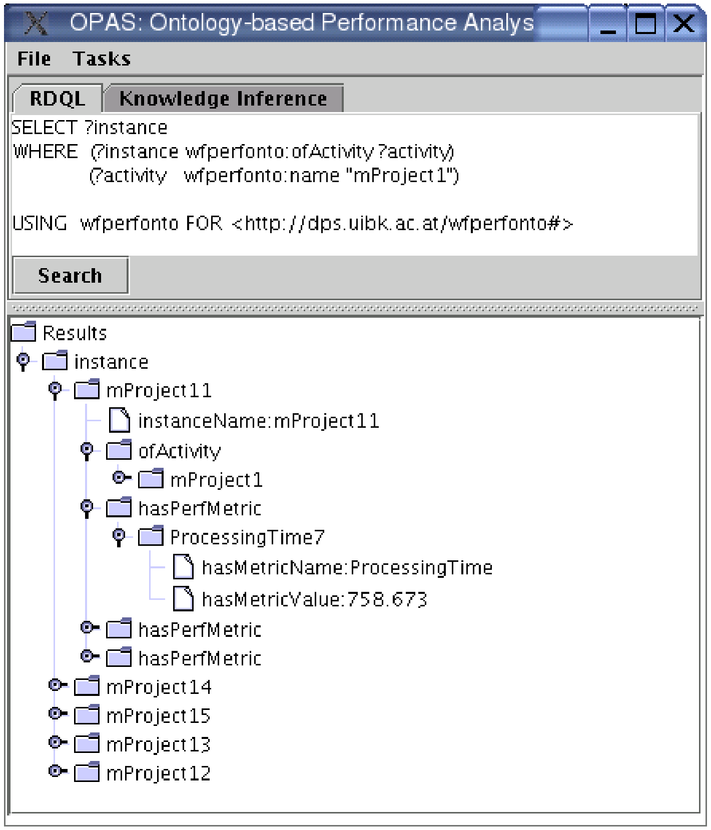


```
<rdf:Description rdf:about="http://dps.uibk.ac.at/wfperfonto#Seq4ForkJoin5">
   <wfperfonto:hasActivityInstance rdf:resource="http://dps.uibk.ac.at/wfperfonto#tRawImage4"/>
   <wfperfonto:hasActivityInstance rdf:resource="http://dps.uibk.ac.at/wfperfonto#tProjectedImage4"/>
   <wfperfonto:hasPerfMetric rdf:resource="http://dps.uibk.ac.at/wfperfonto#ElapsedTime57"/>
   <wfperfonto:hasPerfMetric rdf:resource="http://dps.uibk.ac.at/wfperfonto#QueuingTime59"/>
   <wfperfonto:hasActivityInstance rdf:resource="http://dps.uibk.ac.at/wfperfonto#mProject14"/>
   <wfperfonto:hasActivityInstance rdf:resource="http://dps.uibk.ac.at/wfperfonto#mImgtbl14"/>
   <rdf:type rdf:resource="http://dps.uibk.ac.at/wfperfonto#WorkflowConstructInstance"/>
   <wfperfonto:ofWorkflowConstruct rdf:resource="http://dps.uibk.ac.at/wfperfonto#SeqForkJoin"/>
   <wfperfonto:hasPerfMetric rdf:resource="http://dps.uibk.ac.at/wfperfonto#ProcessingTime58"/>
   <wfperfonto:instanceName>Seq4ForkJoin5</wfperfonto:instanceName>
 </rdf:Description>
```

Utilizing WfPerfOnto: Distributed Performance Analysis



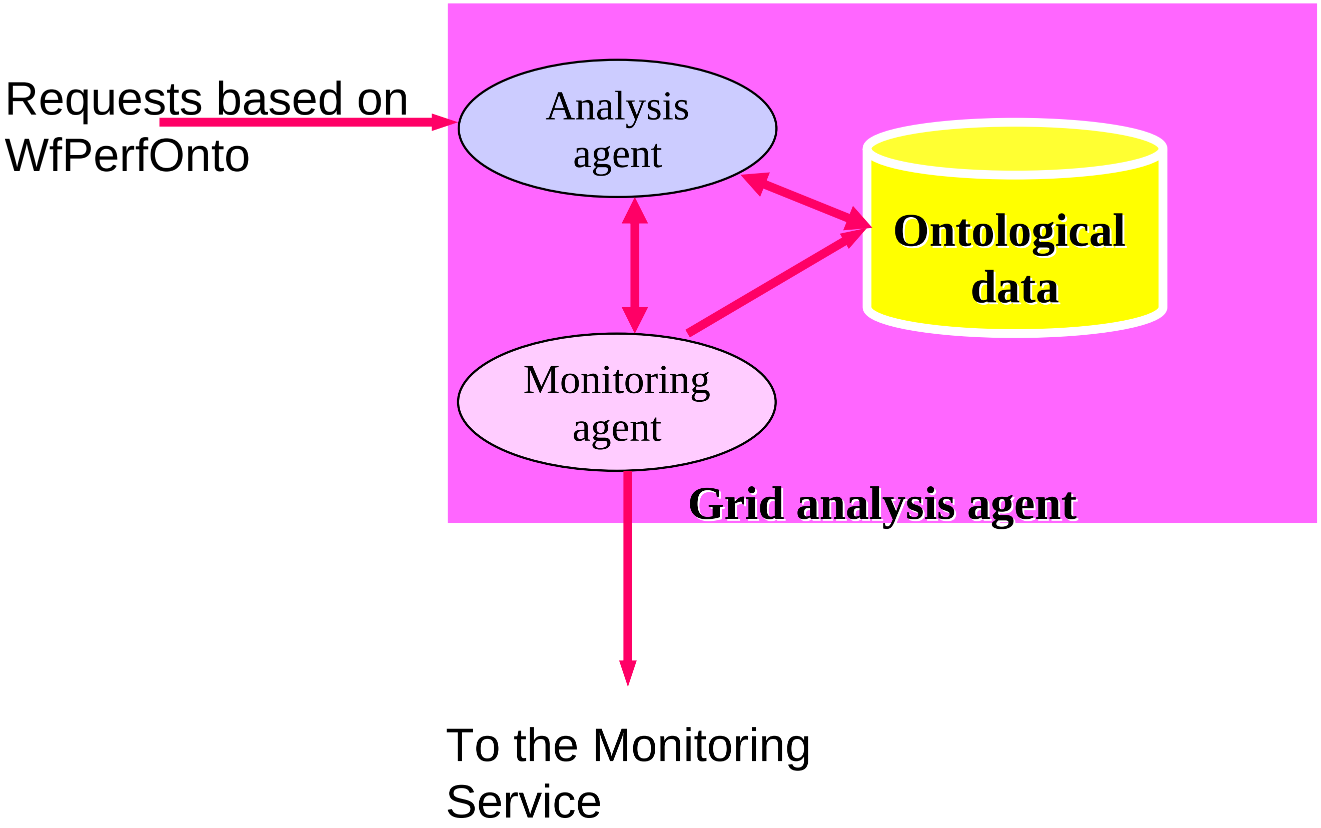
Utilizing WfPerfOnto: Analysis Request



```
SELECT ?instance
WHERE  (?instance wfperfonto:ofActivity ?activity)
          (?activity   wfperfonto:name "mProject1")

USING  wfperfonto FOR <http://dps.uibk.ac.at/wfperfonto#>
```

```
Results
  instance
    mProject11
      instanceName:mProject11
      ofActivity
        mProject1
      hasPerfMetric
        ProcessingTime7
          hasMetricName:ProcessingTime
          hasMetricValue:758.673
      hasPerfMetric
      hasPerfMetric
    mProject14
    mProject15
    mProject13
    mProject12
```



Conclusion and Future Work

- Performance metrics of Grid workflows that characterize the performance and dependability of Grid workflows; metrics associated with multiple levels of abstraction
- Ontology describing performance data of Grid workflows
- Current implementation
  - OWL-based ontologies, Jena toolkit for processing ontology-related task
  - Store and export performance data in/to WfPerfOnto representation
- Future work
  - Extend and revise performance metrics and WfPerfOnto
  - Distributed performance analysis
  - Reasoning performance data

Shared conceptualization → community work?