How Distributed Data Mining Tasks can Thrive as Services on Grids

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Outline

- Introduction
- The Grid for Data Mining
- Data Mining Tasks as Services
- Weka4WS
- Knowledge Grid
- Mobile Data Mining Services
- Final Remarks
Distributed data mining on the Grid

- **Knowledge discovery (KDD) and data mining (DM)**:
  - compute- and data-intensive processes/tasks
  - Often based on distribution of data, algorithms, and users

- The Grid integrates both distributed computing and parallel computing, thus it can be **a key infrastructure** for high-performance distributed knowledge discovery.

- It also offers
  - security, information service, data access and management, communication, scheduling, fault detection, …
Distributed data mining on the Grid

- The Grid extends the distributed and parallel computing paradigms allowing resource negotiation, dynamical allocation, heterogeneity, open protocols and services.

- As the Grid became a well accepted computing infrastructure it is necessary to provide data mining services, algorithms, and applications.

- Those may help users to leverage Grid capability in supporting high-performance distributed computing for solving their data mining problems in a distributed way.
Grid services for distributed data mining

- Exploiting the SOA model and the Web Services Resource Framework (WSRF) it is possible to define basic services for supporting distributed data mining tasks in Grids.

- Those services can address all the aspects that must be considered in data mining and in knowledge discovery processes:
  - data selection and transport services,
  - data analysis services,
  - knowledge models representation services, and
  - visualization services.
Grid services for distributed data mining

- It is possible to define services corresponding to:
  - **Single Steps** that compose a KDD process such as preprocessing, filtering, and visualization.
  - **Single Data Mining Tasks** such as classification, clustering, and association rules discovery.
  - **Distributed Data Mining Patterns** such as collective learning, parallel classification and meta-learning models.
  - **Data Mining Applications or KDD processes** including all or some of the previous tasks expressed through a multi-step workflow.
Data mining Grid services

- This collection of data mining services can constitute an **Open Service Framework for Grid-based Data Mining**

- Allowing developers to design distributed KDD processes as a composition of single services available over a Grid.

- Those services should exploit other basic Grid services for data transfer and management such as
  - Reliable File Transfer (RFT),
  - Replica Location Service (RLS),
  - Data Access and Integration (OGSA-DAI) and
  - Distributed Query processing (OGSA-DQP).
Data mining Grid services

- By exploiting the Grid services features it is possible to develop data mining services accessible every time and everywhere.

- This approach may result in
  - Service-based distributed data mining applications
  - Data mining services for virtual organizations.
  - A sort of knowledge discovery eco-system formed of a large numbers of decentralized data analysis services.
Grid services for distributed data mining

- Service-based systems we developed
  - Weka4WS
  - Knowledge Grid
  - Mobile Data Mining Grid Services
Knowledge Grid
The Knowledge Grid

- Knowledge Grid: a distributed knowledge discovery architecture that can be configured on top of generic Grid middleware
- A first prototype has been implemented on GT2 based on a high-level user interface for application composition (VEGA)
- The Knowledge Grid services are currently being re-implemented as WSRF-compliant Web Services.

Knowledge Grid architecture

High-level K-Grid layer

- DAS (Data Access Service)
- TAAS (Tools and Algorithms Access Service)
- EPMS (Execution Plan Management Service)
- RPS (Result Presentation Service)

Core K-Grid layer

- KMR (Knowledge Directory Service)
- KDS (Knowledge Directory Service)
- RAEMS (Resource Allocation and Execution Management Service)
- KBR
- KEPR

Basic Grid services
The Knowledge Grid and WSRF

- The Knowledge Grid services are currently being re-implemented as **WSRF-compliant Web Services**.

- They can be invoked by client interfaces, programs, and other services

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The Knowledge Grid and WSRF

- Each K-Grid service is exposed as a Grid Service that exports one or more operations using WSRF.
- The operations exported by the High-level K-Grid services are invoked by user-level applications.
- The operations provided by the Core K-Grid services are invoked both by High-level and Core K-Grid services.
<table>
<thead>
<tr>
<th>Service</th>
<th>Operation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>DAS</td>
<td>publishData</td>
<td>This operation is invoked by a client for publishing a newly available dataset. The publishing requires a set of information that will be stored as metadata in the local KMR.</td>
</tr>
<tr>
<td></td>
<td>searchData</td>
<td>Data to be used in a KDD computation is located during the application design by invoking this operation. The searching is performed on the basis of appropriate parameters.</td>
</tr>
<tr>
<td>TAAS</td>
<td>publishTools</td>
<td>This operation is used to publish metadata about a data mining tool in the local KMR. As a result of the publishing, a new DM service is made available for utilization in KDD computations.</td>
</tr>
<tr>
<td></td>
<td>searchTools</td>
<td>It is similar to the searchData operation except that it is targeted to data mining tools.</td>
</tr>
</tbody>
</table>
Knowledge Grid: Service operations

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<tr>
<th>Service</th>
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<tr>
<td>EPMS</td>
<td><strong>submitKApplication</strong></td>
<td>This operation receives a conceptual model of the application to be executed. The EPMS generates a corresponding abstract execution plan and submits it to the RAEMS for its execution.</td>
</tr>
<tr>
<td>RPS</td>
<td><strong>getResults</strong></td>
<td>Retrieves results of a performed KDD computation and presents them to the user.</td>
</tr>
<tr>
<td>KDS</td>
<td><strong>publishResource</strong></td>
<td>This is the basic, core-level operation for publishing data or tools. It is thus invoked by the DAS or TAAS services for performing their own specific operations.</td>
</tr>
<tr>
<td></td>
<td><strong>searchResource</strong></td>
<td>The core-level operation for searching data or tools.</td>
</tr>
<tr>
<td>RAEMS</td>
<td><strong>manageKExecution</strong></td>
<td>This operation receives an abstract execution plan of the application. The RAEMS generates an instantiated execution plan and manages its execution.</td>
</tr>
</tbody>
</table>
Weka4WS
The Weka4WS framework

- **Weka** is one of the most used open source suite for data mining.

- In Weka, the overall data mining process takes place on a single machine; the algorithms can be only locally executed.

- **Weka4WS** extends Weka to support distributed execution of the Weka data mining algorithms
  - All data mining algorithms provided by the Weka library are exposed as WSRF-compliant Web Services
  - Globus Toolkit 4 is used for basic Grid functionalities such as security and data transfer.

**Weka4WS architecture**

- We distinguish Weka4WS nodes in two categories:
  - *user nodes*, which are the local machines of the users providing the Weka4WS client software
  - *computing nodes*, which provide the Weka4WS Web Services allowing the execution of remote data mining tasks

- Data can be located on *computing nodes*, *user nodes*, or third-party nodes

- If the dataset to be mined is not available on a computing node, it can be copied or replicated by means of the GT4 data management services.
Software components

- User nodes include three software components:
  - Graphical User Interface (GUI)
  - Client Module (CM)
  - Weka Library (WL)
Computing nodes include two software components:
- Web Service (WS)
- Weka Library (WL)
The GUI extends the Weka Explorer environment to allow the execution of both local and remote data mining tasks:

- *local tasks* are executed by directly invoking the local WL
- *remote tasks* are executed through the CM, which operates as an intermediary between the GUI and Web Services on remote computing nodes
The WS is a WSRF-compliant Web Service that exposes the data mining algorithms provided by the underlying Weka Library.

Requests to the WS are executed by invoking the corresponding WL algorithms.
Weka4WS Graphical User Interfaces

- Weka4WS extends the GUls of Weka:
  - **Explorer**
  - available with **Weka4ws 1.0** (grid.deis.unical.it/weka4ws)
  - **KnowledgeFlow**
- A “Control panel” allows users to submit both local and remote tasks has been added to the original Weka Explorer environment
Weka4WS Explorer

- A drop down menu allows to choose where to run the current data mining task ("Local", "Auto", or a specific host)
- A button allows to reload the list of hosts and check for the availability of the Globus container on each host
- A button allows to stop, if needed, both the local and the remote computation of the data mining tasks
Each task in the GUI is managed by an independent thread. A user can start multiple data mining tasks at the same time on different remote hosts.
The detailed log allows to follow the remote computations step by step
- Whenever the output of a data mining task has been received from a remote computing node, it is visualized in the standard Output panel.
A data mining workflow can be composed and run on several Grid nodes.
Mobile Data Mining Grid Services
Grid Services for Mobile Data Mining

- The main research goal is to support a user to access data mining services on mobile devices.
- The system includes three components:
  - Data providers.
  - Mining servers.
  - Mobile clients.
The Mining server

- A Mining server implements two Grid Services:
  - **Data Collection Service (DCS):** invoked by a data provider to store data in the data store.
  - **Data Mining Service (DMS):** invoked by a mobile client to ask for the execution of a data mining task.
Grid Services for Mobile Data Mining

- A user can select which part of a result (data mining model) he wants to visualize.
Impact of the WSRF overhead

- Execution times

It can be observed that the data mining phase takes approximately from 95% to 99% of the total execution time.

Thus the overhead due to the WSRF invocation mechanisms is negligible for typical data mining tasks on large datasets.
Impact of the WSRF overhead

- **Execution times**

  ![Graph showing execution times for various steps like data mining, dataset download, etc.]

  - In a larger scenario the data mining step represents from 85% to 88% of the total execution time, the dataset download takes about 11%, while the other steps range from 4% to 0.5%
**Weka4WS: application speedup on a Grid**

![Graph of execution time vs. number of nodes]

**Graph:**
- X-axis: Number of nodes
- Y-axis: Execution time (s)

![Graph of speedup vs. number of nodes]

**Graph:**
- X-axis: Number of nodes
- Y-axis: Speedup

**Legend:**
- Δ: Data point

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Final remarks

- Single data mining tasks can be delivered as Grid services, knowledge discovery processes can be implemented as complex Grid services.

- Scientific and Business VOs can benefit from their integration and availability.

- Systems like the KNOWLEDGE GRID and Weka4WS show the effectiveness of the approach.

- In a long-term vision, pervasive collections of data mining services and applications will be accessed and used as public utilities.
Thank you!

Credits:

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Andrea Pugliese
Oreste Verta
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