Data-Intensive Research with DISPEL

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(in collaboration with all the ADMIRE project consortium)
Special thanks to Malcolm Atkinson, from whom most of the slides have been reused

Recognition slide…

- There are many names of many people who have contributed to these slides
  - I am almost just a simple story-teller or work done by others…
- Difficult to provide all names
  - Especially when you finish compiling slides the day before.
  - This slide will be completed for the online version with all names
- For simplicity, thanks to the ADMIRE consortium members

Overview

- Motivational examples
- DISPEL: a language for data-driven research
  - Architecture
  - DISPEL components
    - Processing Elements
    - Types
    - Functions
- DISPEL processing/evaluation
  - The role of the DISPEL gateway
  - The role of the DISPEL registry
- DISPEL resources

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Motivational Examples

- Astronomy: detection of quasars
- Seismology: ambient noise data processing
- CRM: customer churn and cross-selling
- Genetics: understanding mouse embryos

Motivational Examples

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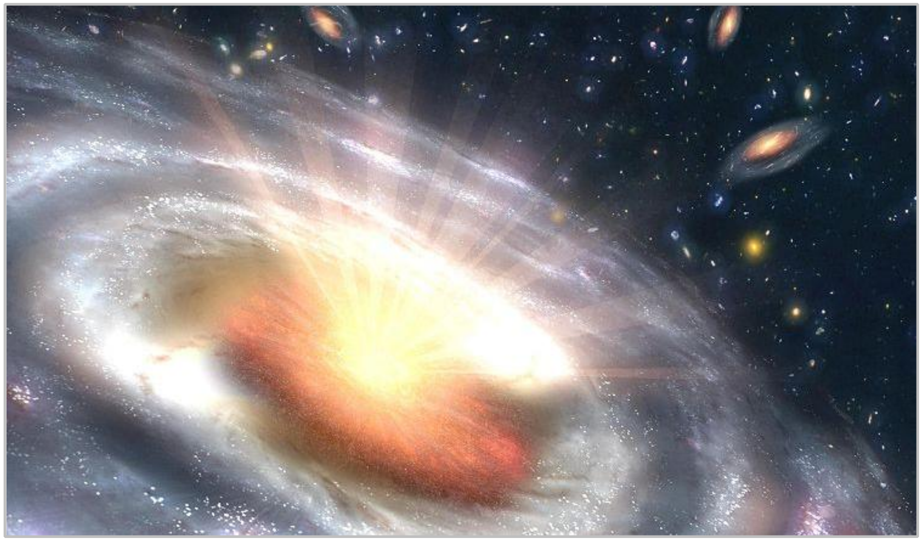
Quasars

- Quasars are highly energetic cores of galaxies, where matter is falling into black holes, releasing prodigious quantities of energy in the process.
- Star-like in appearance (quasi-stellar radio sources)
- Distinguishing quasars from stars requires information from the distribution of their light across the electromagnetic spectrum.
- Most star-like objects are stars not quasars.



Detection of quasars

Traditional method:

- Spectroscopic
- Expensive
- Slow
- Single object

Alternative method:

- Photometric
- Cheaper
- Quicker
- All objects in area
- Combine multiple bands to approximate spectroscopic study

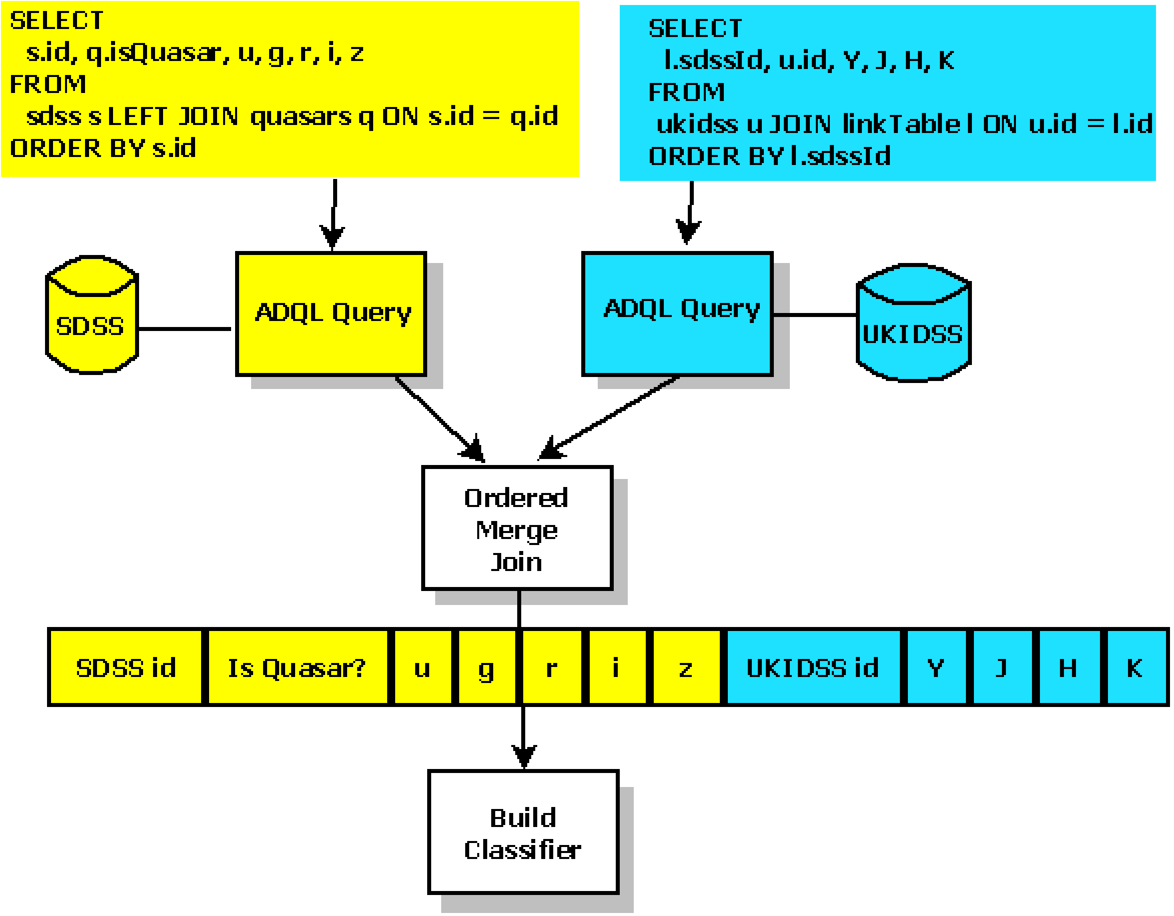
- Classification using 5 photometric bands has been shown to be good at classifying quasars.
- Research question: Does using 9 photometric bands improve the classification?

The data

- Sloan Digital Sky Survey (SDSS)
  - 450m astronomical features
  - 5 optical wavelength bands (u, g, r, i, and z)
  - 120,000 spectroscopically confirmed quasars
- UKIRT Infrared Deep Sky Survey (UKIDSS)
  - 60m astronomical features
  - 4 infrared wavelengths (Y, J, H, and K)
  - Link table with distances between objects in SDSS and UKIDSS

SDSS id	Is Quasar?	u	g	r	i	z	UKIDSS id	Y	J	H	K

Data Integration Workflow



```
SELECT
  s.id, q.isQuasar, u, g, r, i, z
FROM
  sdss s LEFT JOIN quasars q ON s.id = q.id
ORDER BY s.id
```

```
SELECT
  l.sdssId, u.id, Y, J, H, K
FROM
  ukidss u JOIN linkTable l ON u.id = l.id
ORDER BY l.sdssId
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SDSS id	Is Quasar?	u	g	r	i	z	UKIDSS id	Y	J	H	K

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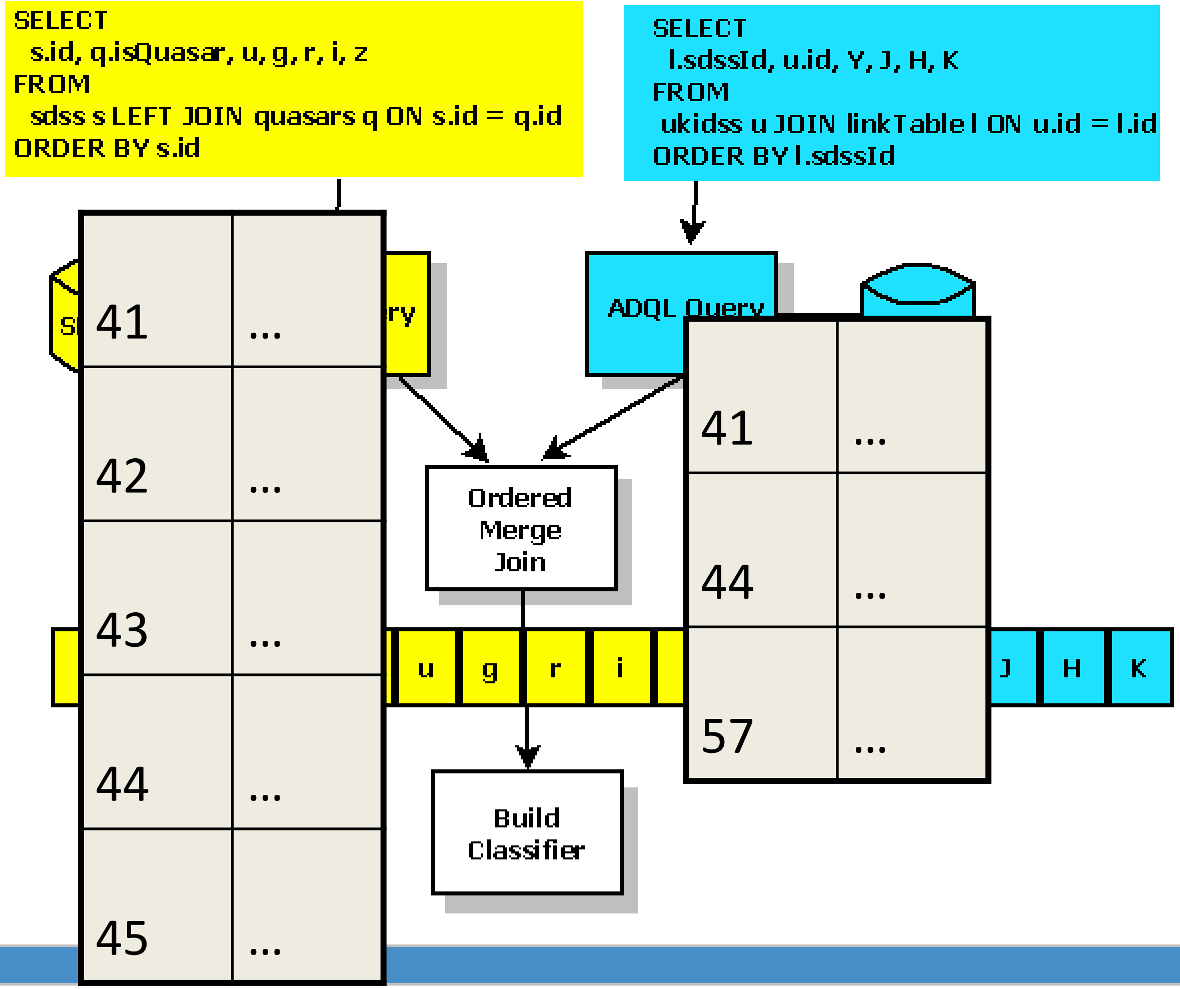

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```
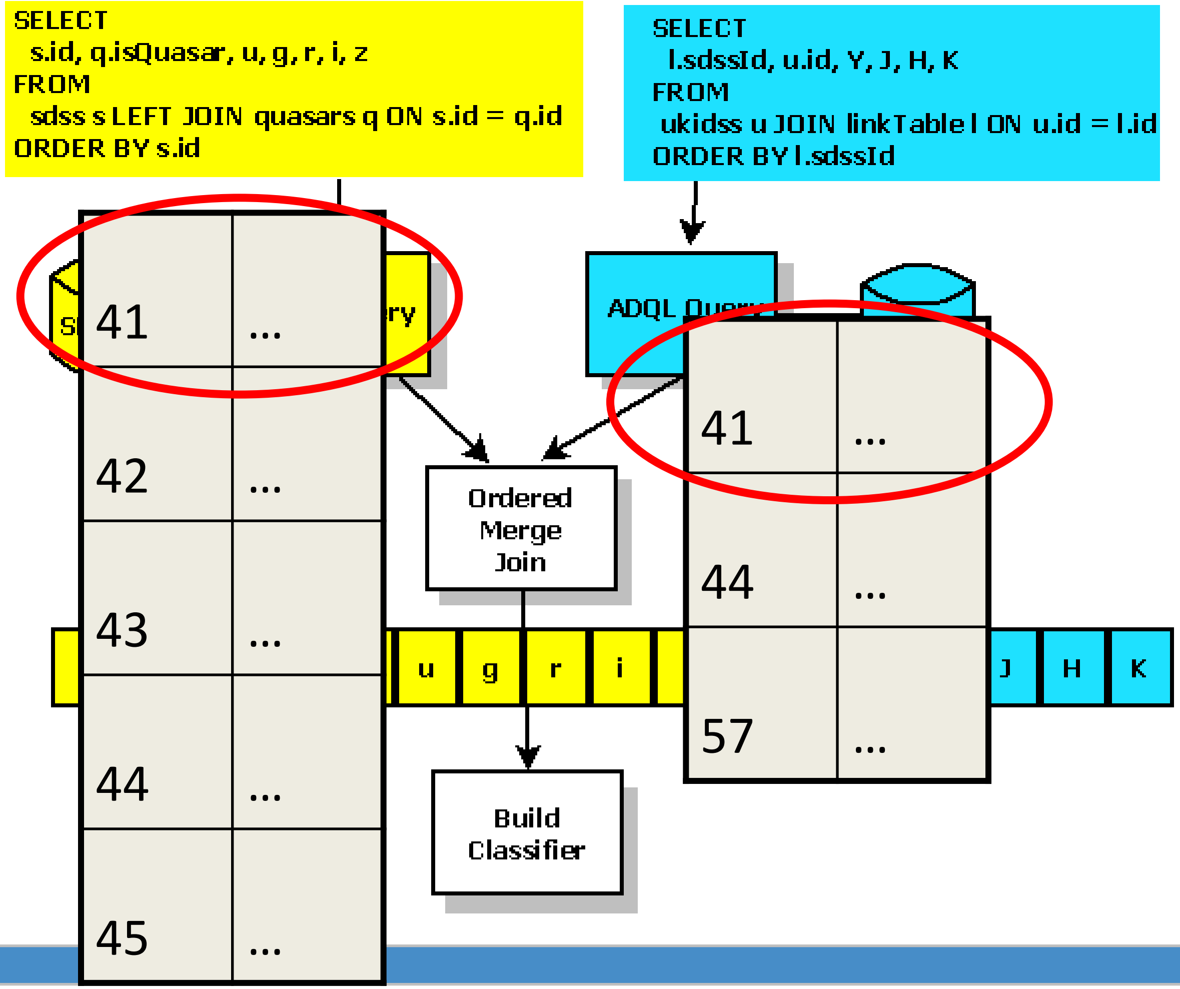

41	…
42	…
43	…
44	…
45	…

41	…
44	…
57	…

Data Integration Workflow



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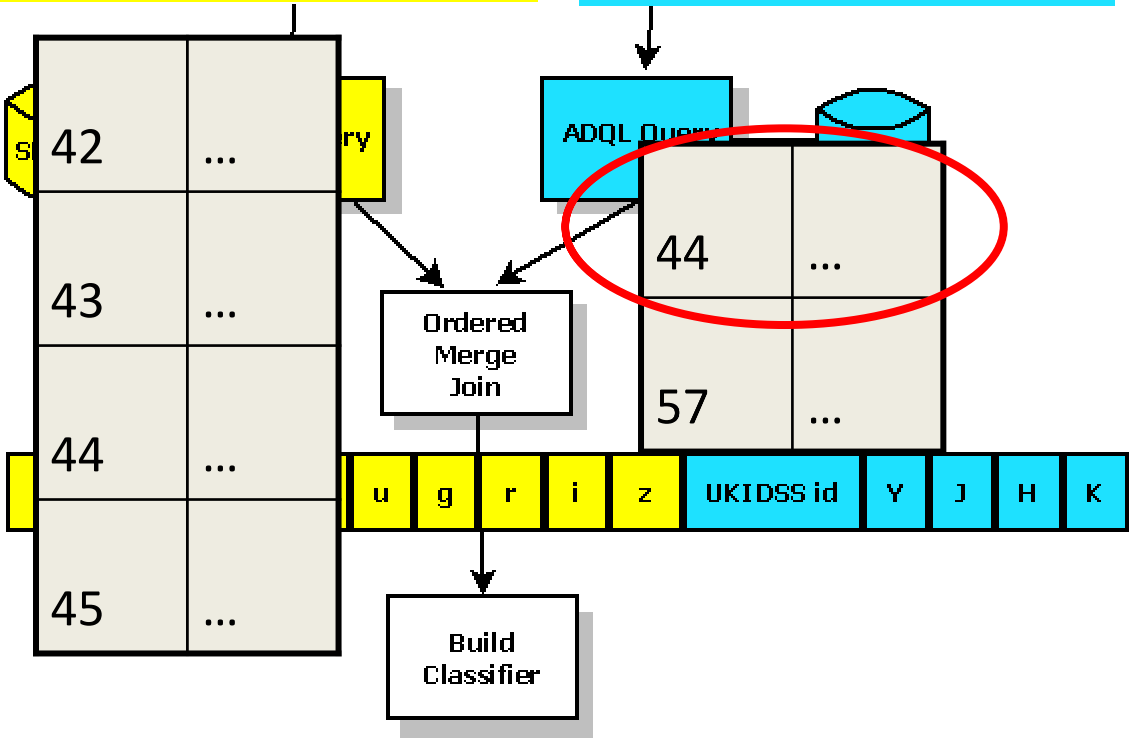

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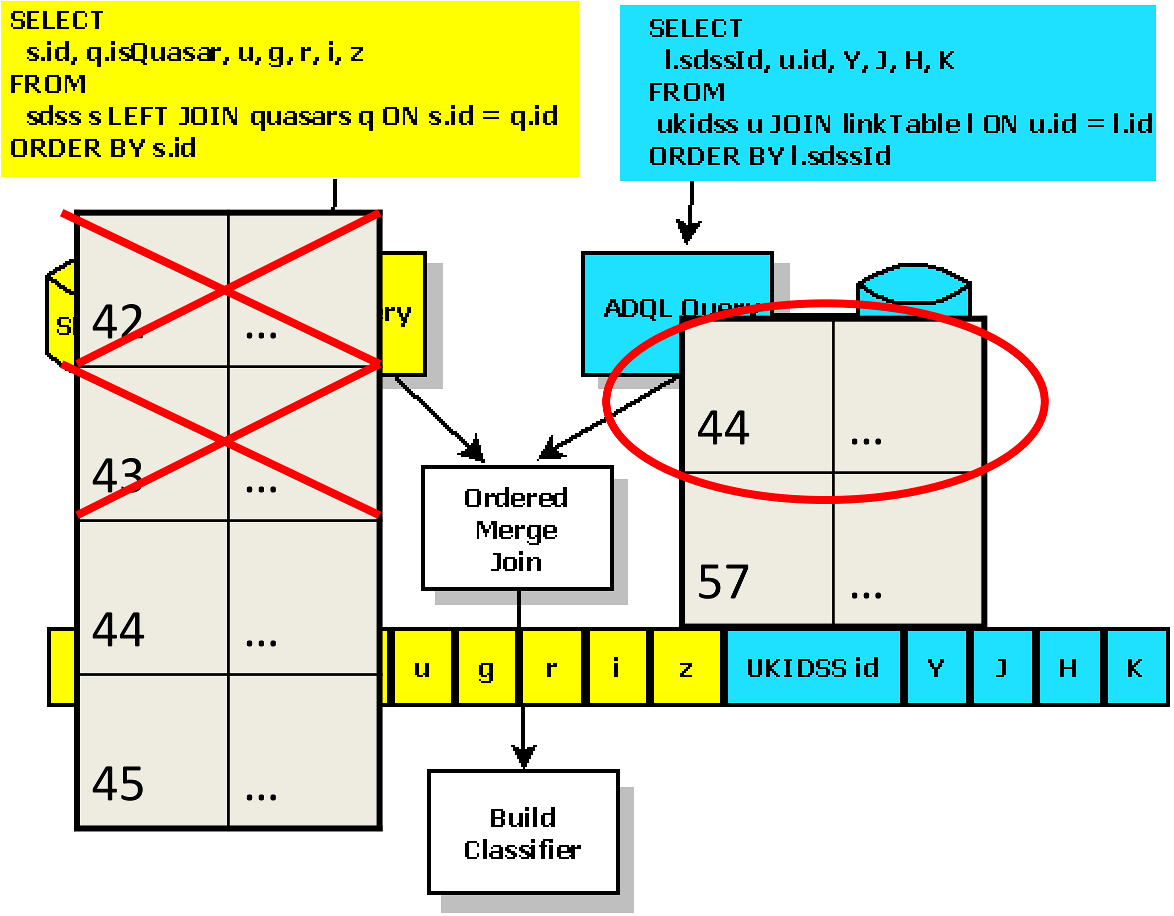

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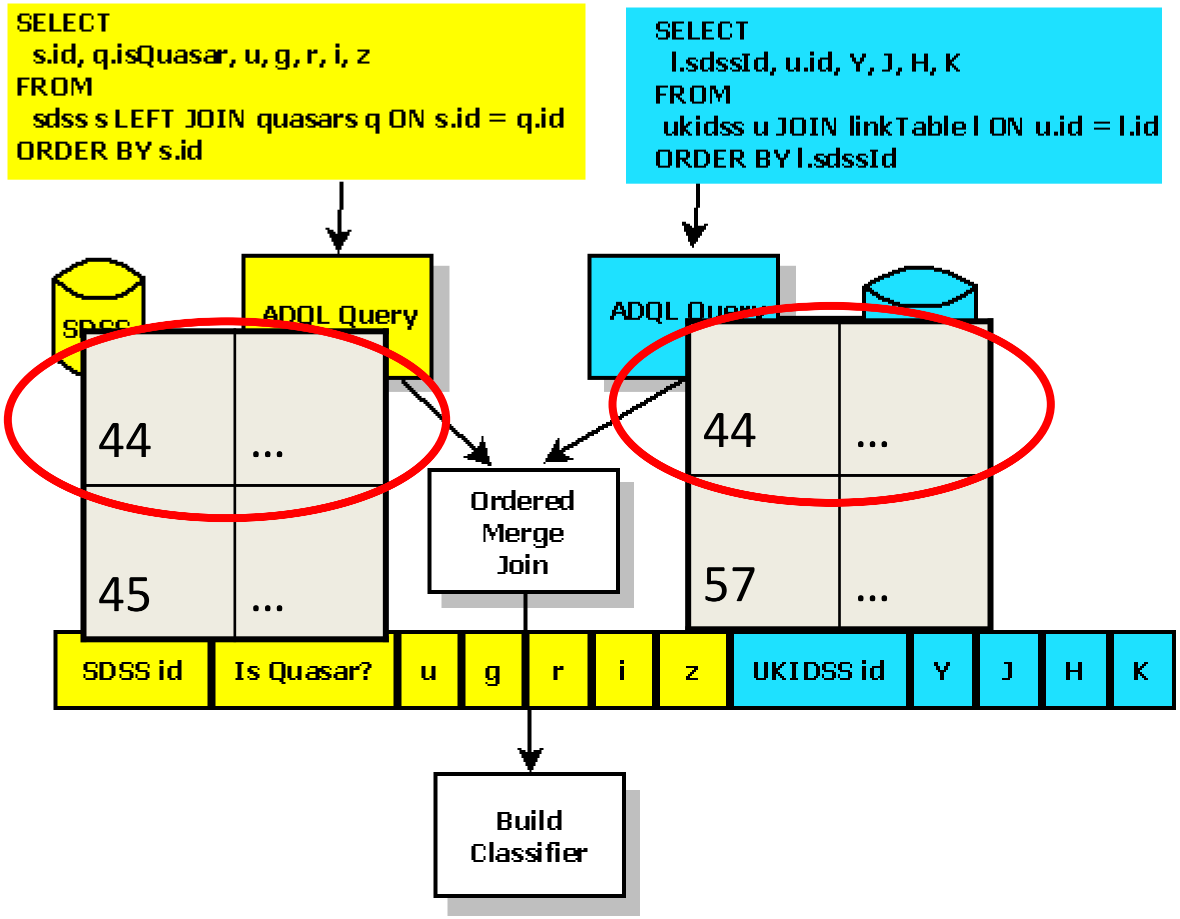

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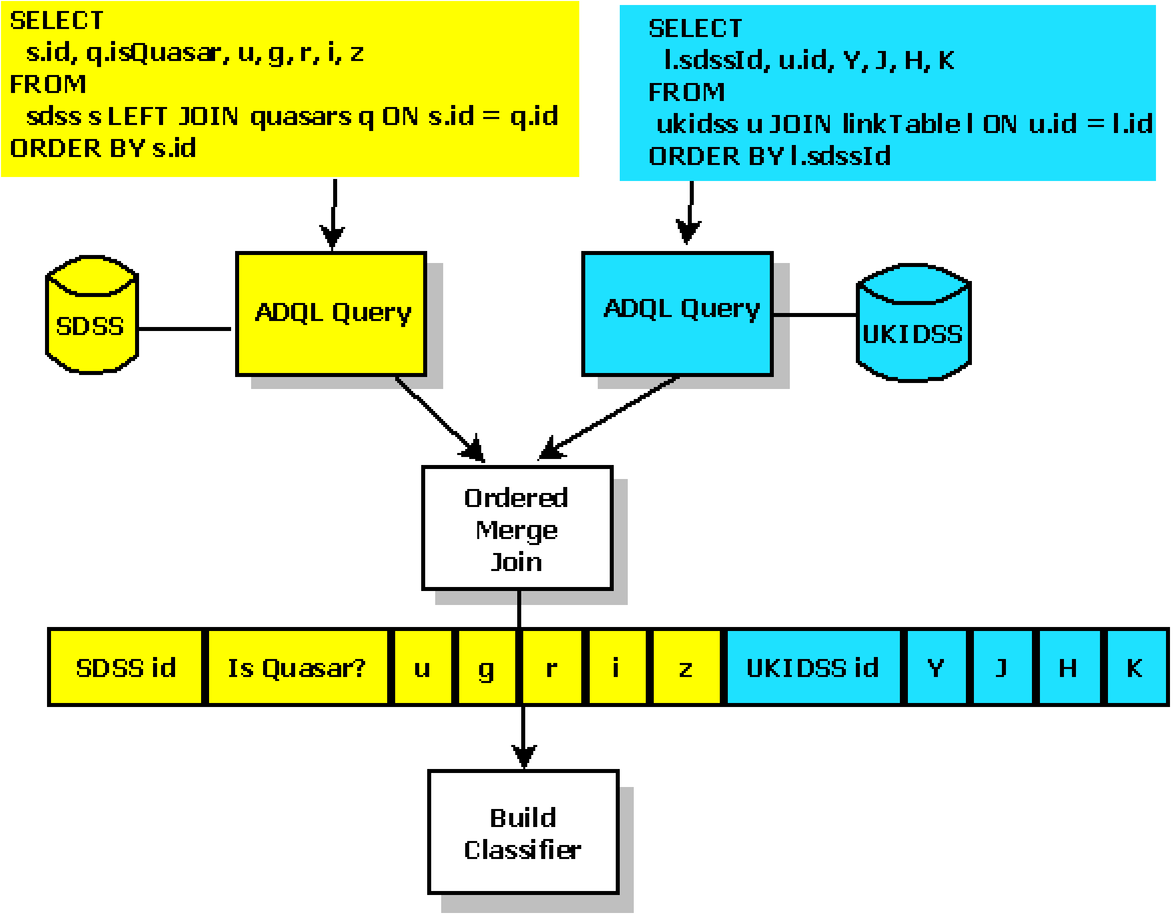

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Motivational Examples

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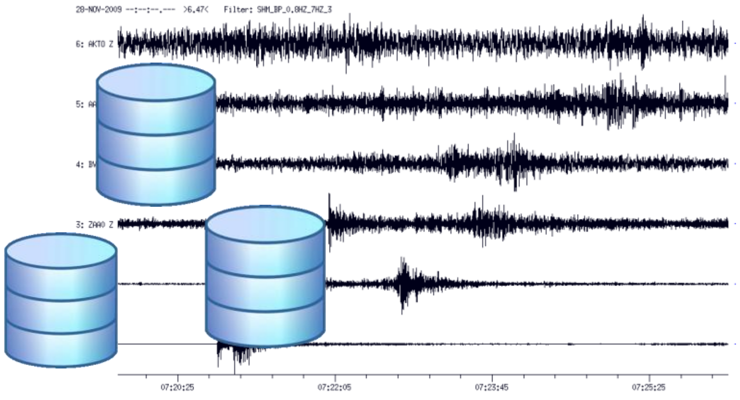
Ambient Noise Data Processing

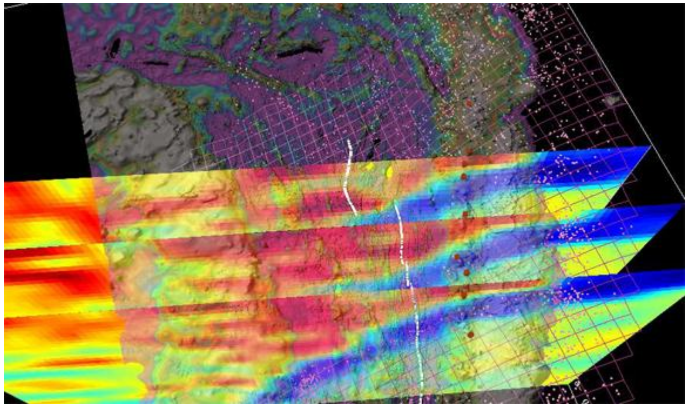


Time segmentation

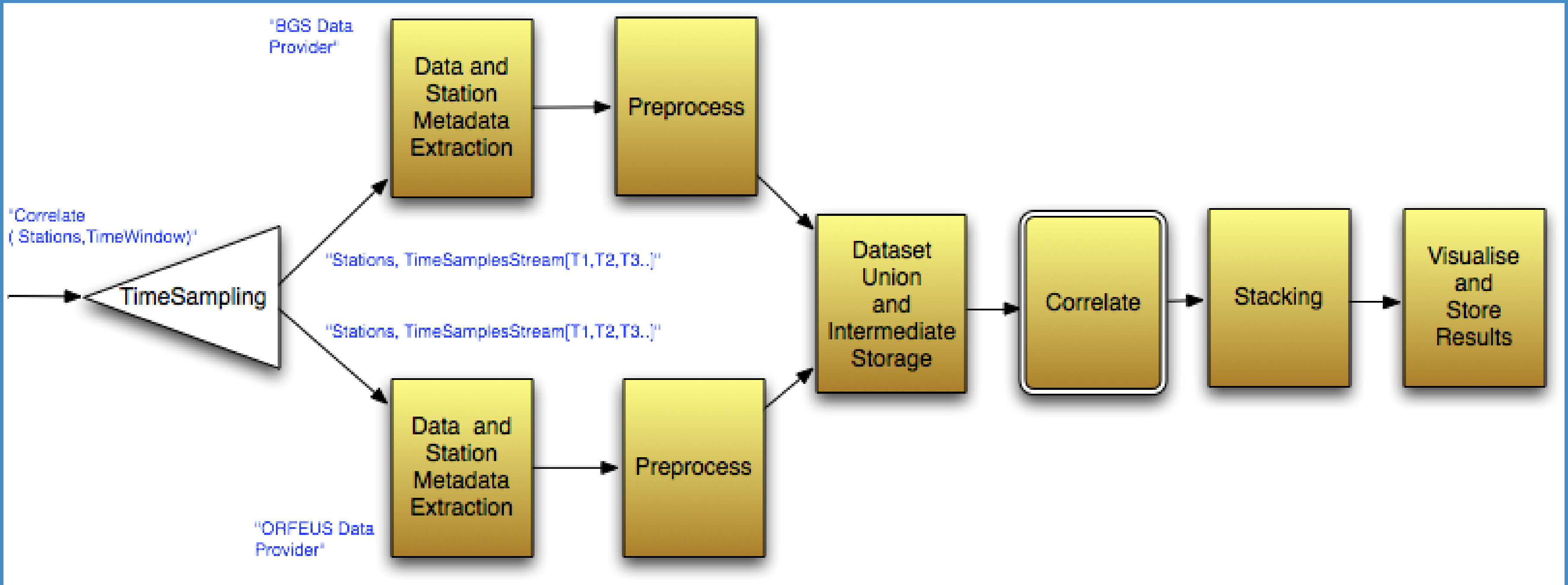
Filtering & normalization

Cross-correlation & stacking

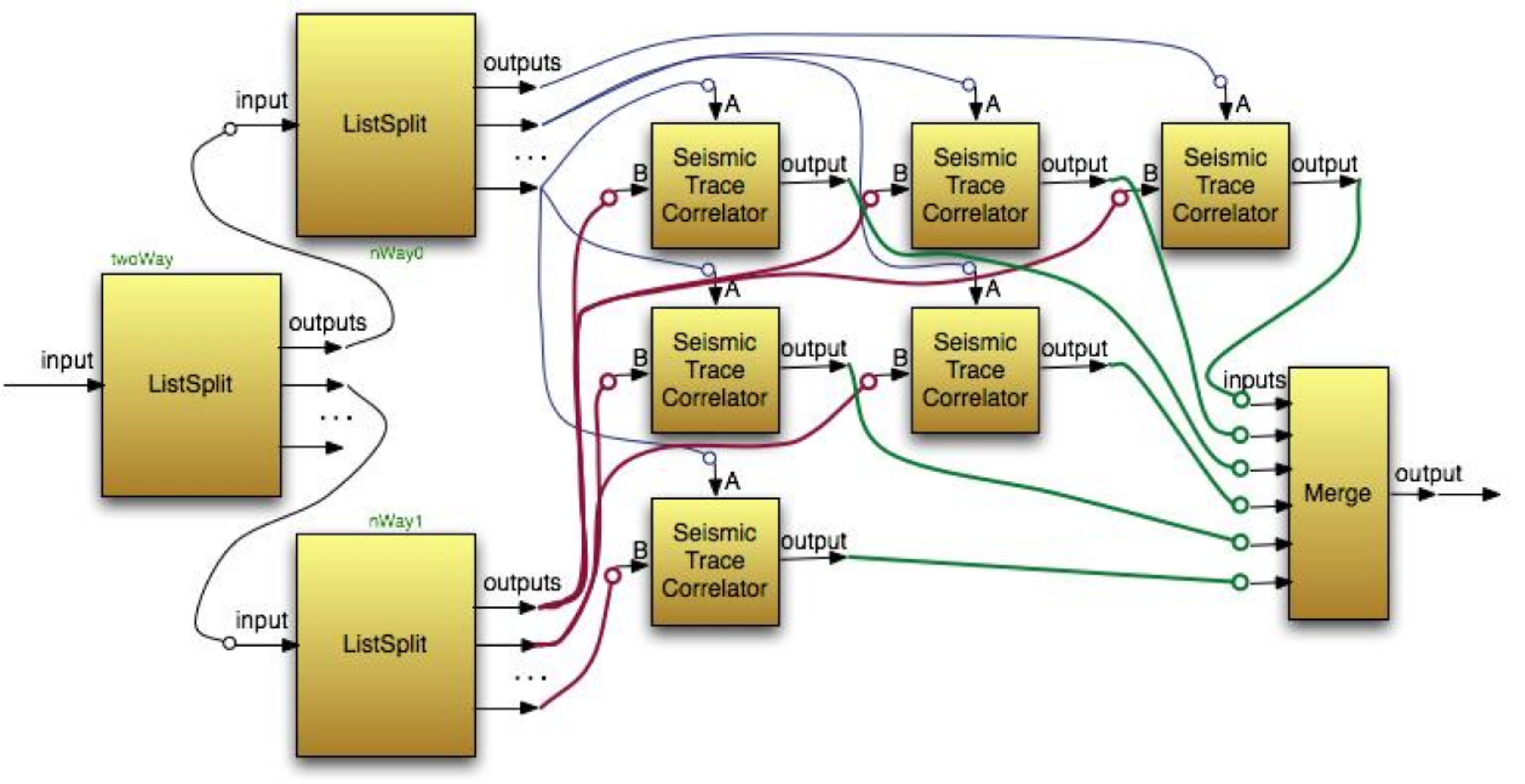
⋮



High level workflow


"BGS Data Provider"
Data and Station Metadata Extraction
Preprocess
"Correlate (Stations,TimeWindow)"
TimeSampling
"Stations, TimeSamplesStream[T1,T2,T3..]"
"Stations, TimeSamplesStream[T1,T2,T3..]"
Dataset Union and Intermediate Storage
Correlate
Stacking
Visualise and Store Results
Data and Station Metadata Extraction
Preprocess
"ORFEUS Data Provider"

Cross-correlations



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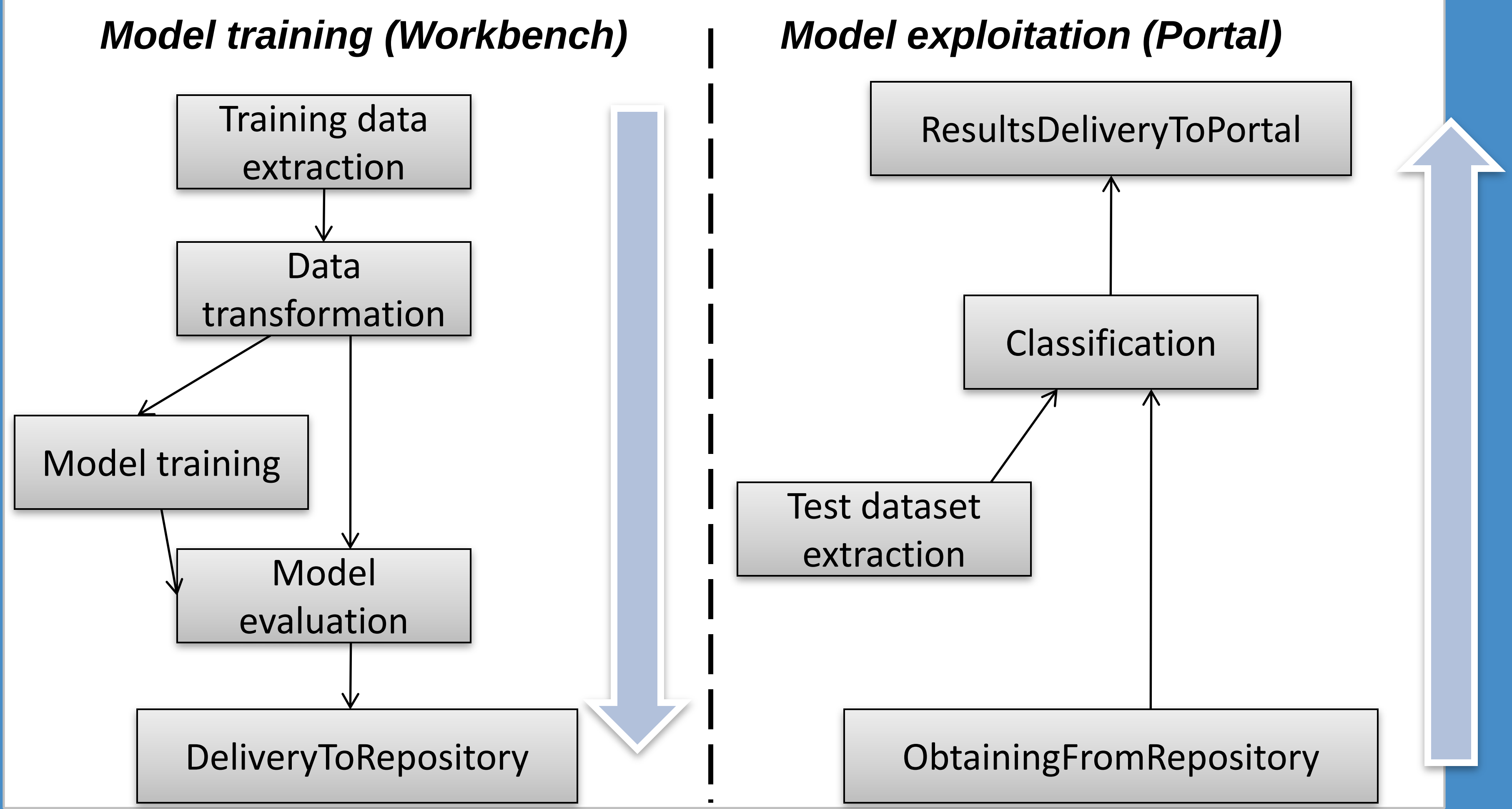
CRM Customer Churn Prediction

- Business goal
  - Recognize customers that are probable to quit company services
  - Find out which conditions influence churning
- Knowledge discovery phases
  - Model training
    - Designed and executed by data analyst
    - Long-lasting and complicated
  - Model exploitation
    - Executed by domain experts (calling agents)
    - Quick and simple

Architecture



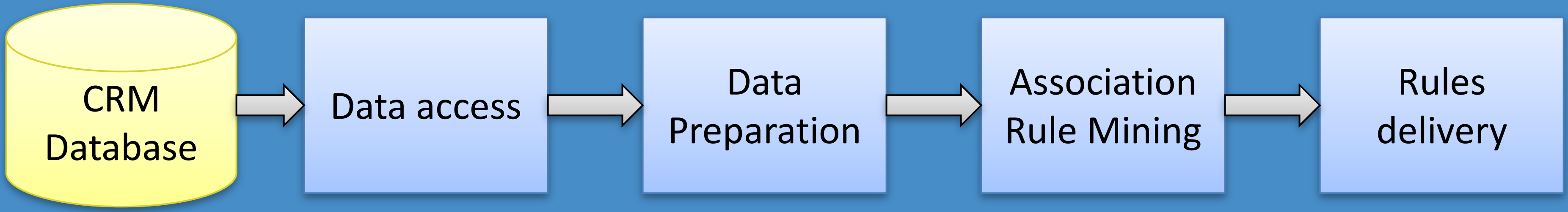
CRM Cross-Selling

- Business goal
  - To find out hints about additional products or services to be provided to potential customers
  - Market analysis

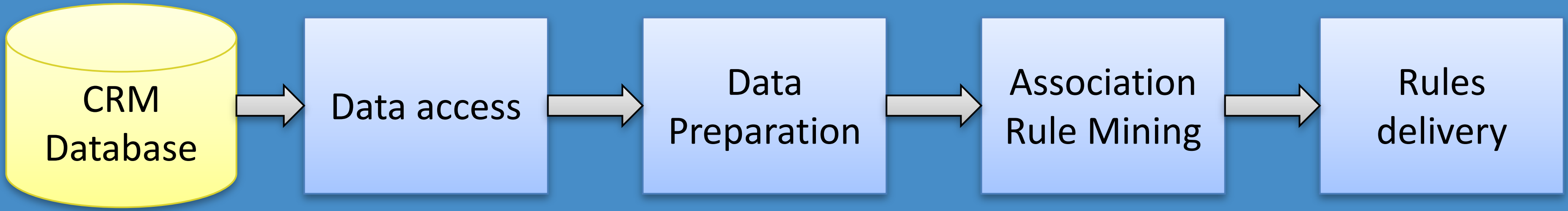
- Knowledge discovery
  - Get frequent itemsets/association/sequential rules from historical data set

    Roaming = TRUE & GSM_Prepaid = TRUE => Voice_mail = TRUE

Architecture



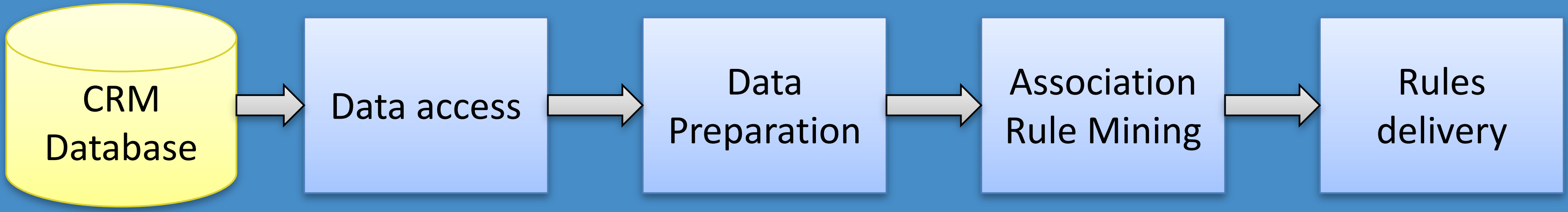
Architecture



AGE	LONGEVITY
35	3
21	38

AGE	LONGEVITY
MEDIUM	SHORT
YOUNG	LONG

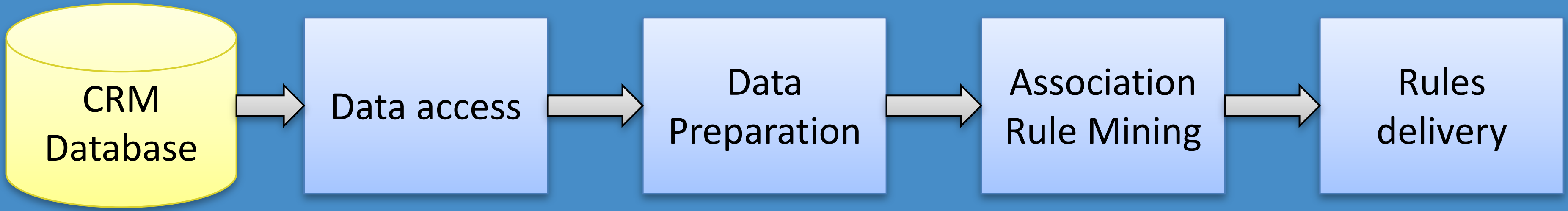
Architecture



CID	PRODUCT
1	GSM_Prepaid
1	Roaming

CID	GSM_PREPAID	Voice_mail	Roaming	Internet access
1	TRUE	FALSE	TRUE	FALSE

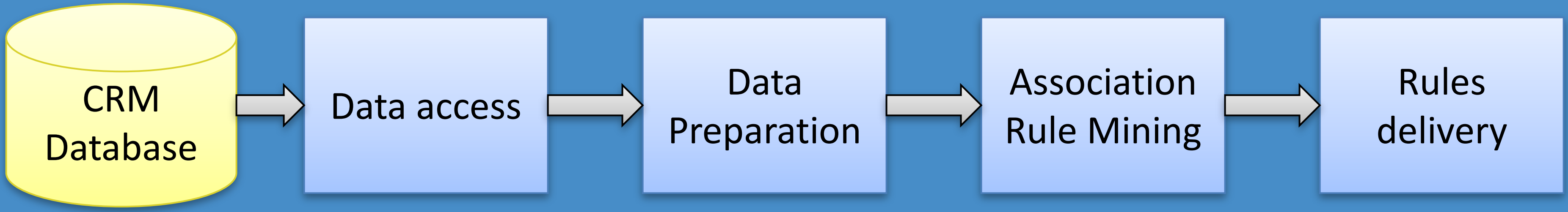
Architecture



GSM_Prepaid	Voice_mail	Roaming	Internet access	Age	Longevity
TRUE	FALSE	TRUE	FALSE	YOUNG	LONG
…	…	…	…	…	…

GSM_Prepaid = TRUE & Age = YOUNG => Roaming = TRUE

Architecture



GSM_Prepaid = TRUE & Age = YOUNG => Roaming = TRUE

```
...
<_40:AssociationModel minimumConfidence="0.3" minimumSupport="0.01" numberOfItems="6"
numberOfItemsets="12" numberOfRules="25" numberOfTransactions="4525">
 <_40:Item id="0" value=„GSM_Prepaid=TRUE"/>
 <_40:Item id="1" value=„Age=YOUNG"/>
 <_40:Item id="2" value=„Roaming=TRUE”/>
…
```

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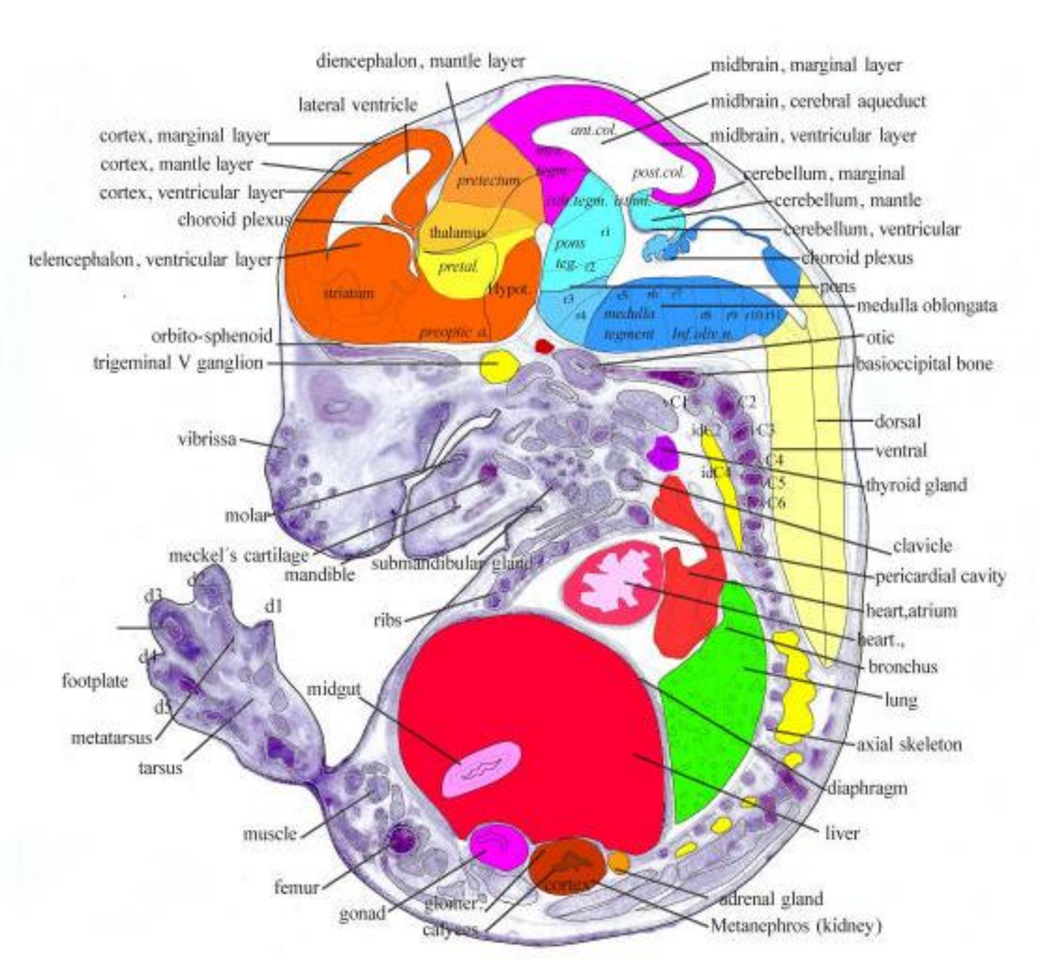
Understanding Mouse Embryos

- Understand the gene function and interactions of genes in a mouse embryo
- Generate a collection of images by employing RNA *in-situ* hybridisation process
- Identify anatomical components expressing as a gene by annotating the images

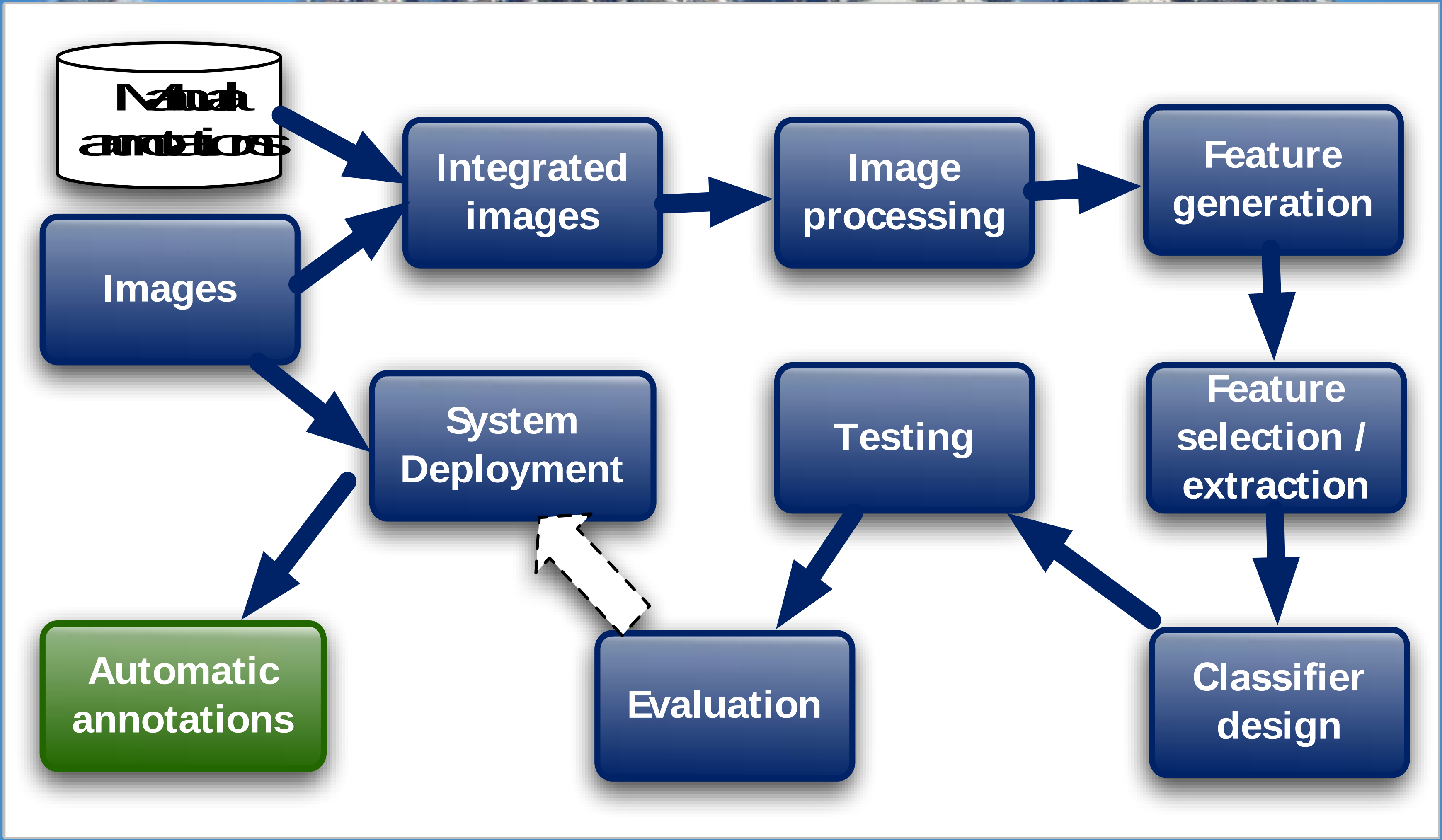
Annotated Mouse Embryo



The Numbers

- 18,000 genes’ collection for mouse embryo established by RNA *in-situ* hybridisation
- 1,500 anatomical terms ontology used for annotations
- 4 Terabytes of images
  - 80% manually annotated
  - 20% remaining (over 85,000 images)

EURExpress-II Workflow



Manual annotations

Images

Integrated images

Image processing

Feature generation

Feature selection / extraction

Classifier design

Testing

Evaluation

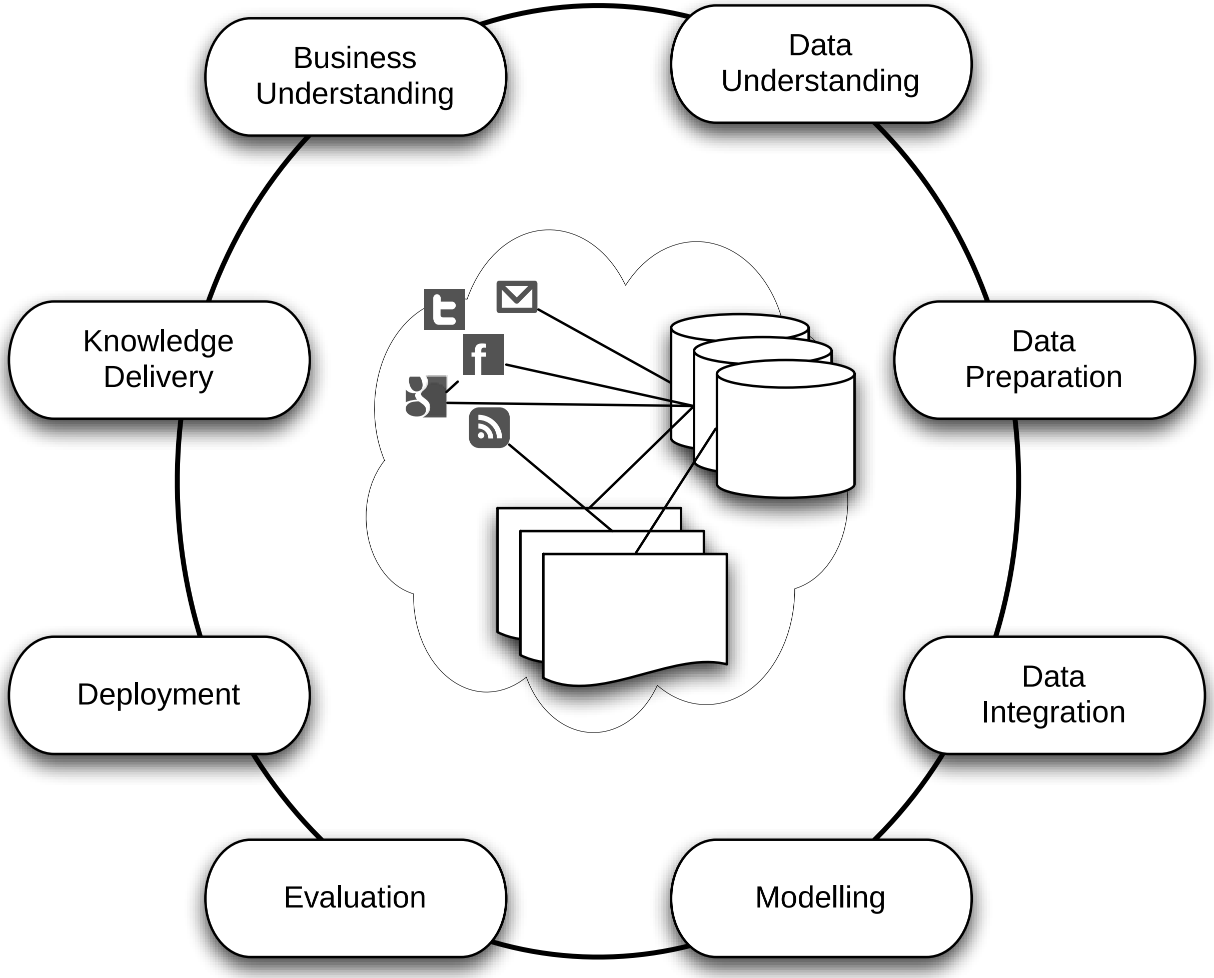
System Deployment

Automatic annotations

Motivational Examples

What do they all have in common?

The Knowledge Discovery Process



Motivational Examples

- Common characteristics
  - Need for a range of data mining and integration functionalities
  - Large-scale data
    - Most of traditional/widely-available tools are not enough
    - Need to manage streaming-based models
    - Sometimes high computational demand
  - Domain experts become data mining and integration experts, and even distributed computing experts
    - Such specialised human resources are difficult to find

Motivational examples

- What do we need then?
  - An all-in-one framework that combines…
    - Data integration, processing and mining
  - Extensible with domain specific requirements
    - e.g., ADQL queries in Astronomy
  - Support for reusable building blocks
    - e.g., n-fold validation
  - Support for distributed and parallel execution of workflows
  - Native support for a streaming data model
    - e.g., ordered merge joins
  - Automated optimisation

Motivational examples

- What do we need then (cont.)?
  - A framework that separates concerns of
    - Domain Experts
      - They understand the problems of their domain, and the datasets to be used
    - Data-intensive Analysts
      - They understand the knowledge discovery process and know the algorithms and techniques to be used (e.g., association rules, clustering, etc.)
    - Data-intensive Engineers
      - They understand the foundations of distributed computing, and their platforms and technologies (e.g., Grid Computing, Clouds, etc.)

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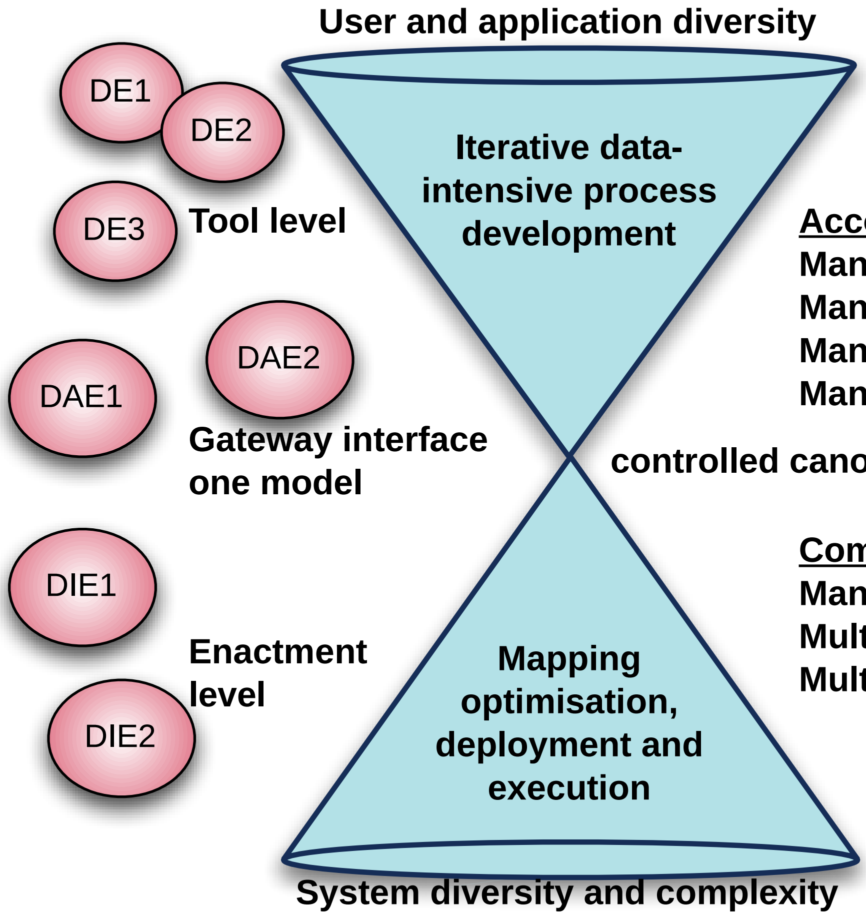
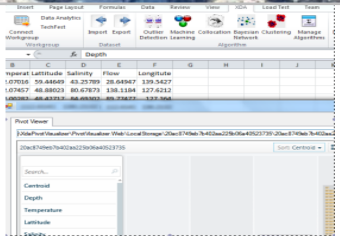
The DISPEL Hourglass


User and application diversity
DE1
DE2
DE3
Tool level
Iterative data-intensive process development
DAE1
DAE2
Gateway interface
one model
DIE1
DIE2
Enactment level
Mapping optimisation, deployment and execution
System diversity and complexity



B	C	D	E	F
nperat	Lattitude	Salinity	Flow	Longitute
.07016	59.44649	43.25789	28.64947	139.5427
.07457	48.88023	80.67873	138.1184	127.6212

<u>Accommodating and facilitating</u>

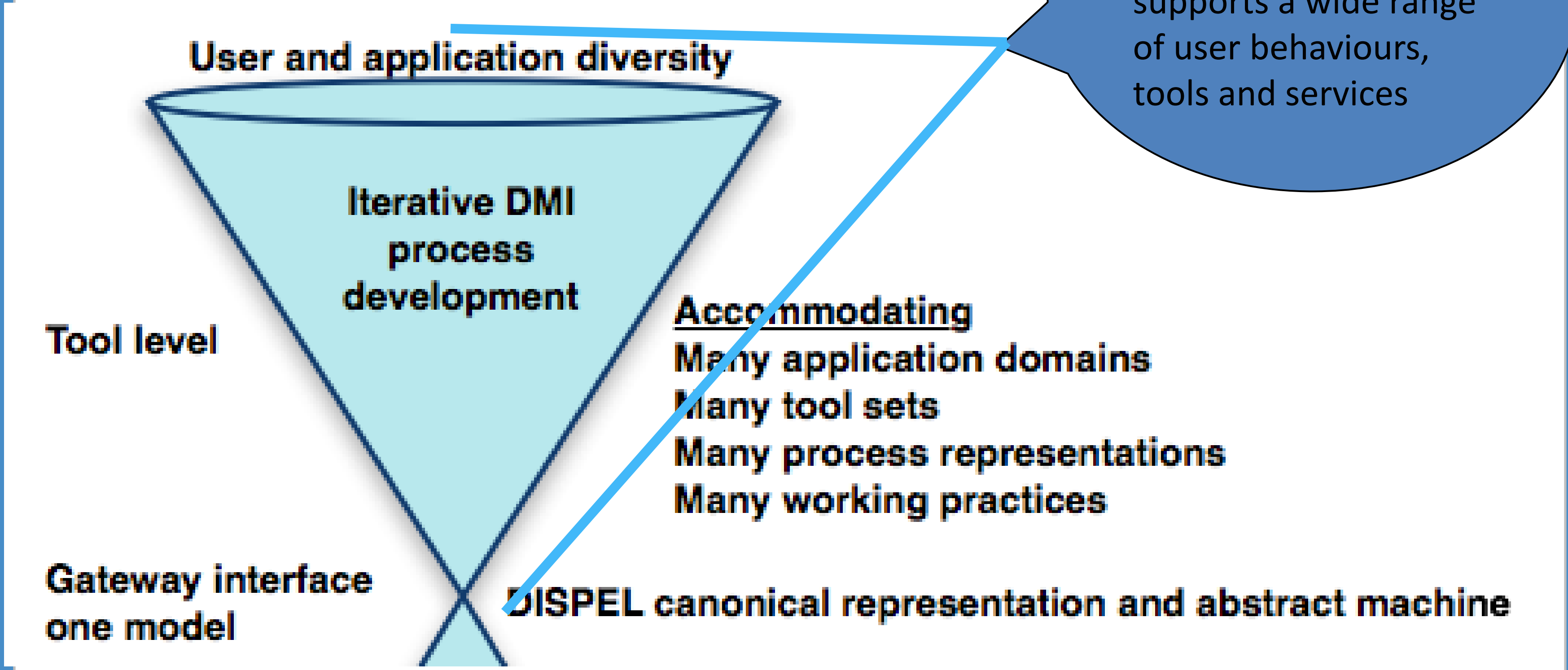
Many application domains
Many tool sets
Many process representations
Many working practices

controlled canonical representation

<u>Composing and providing</u>

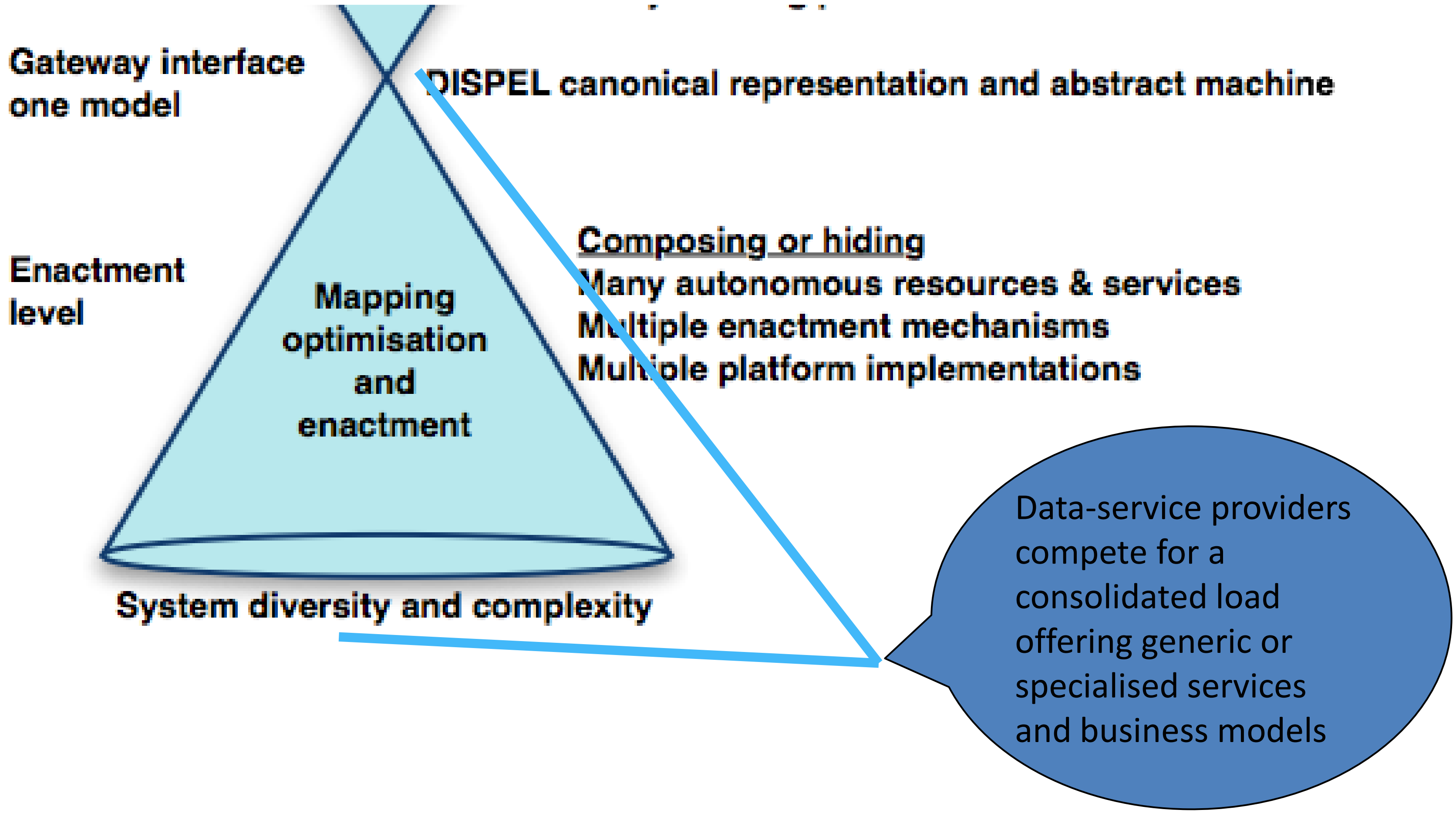
Many autonomous resources
Multiple enactment mechanisms
Multiple platform implementations

The DISPEL Hourglass


User and application diversity
Iterative DMI process development
Tool level
Accommodating
Many application domains
Many tool sets
Many process representations
Many working practices
Gateway interface one model
DISPEL canonical representation and abstract machine

Data-exploitation develops diversity and supports a wide range of user behaviours, tools and services

The DISPEL Hourglass



Gateway interface
one model

DISPEL canonical representation and abstract machine

Enactment
level

Mapping
optimisation
and
enactment

Composing or hiding
Many autonomous resources & services
Multiple enactment mechanisms
Multiple platform implementations

System diversity and complexity

Data-service providers compete for a consolidated load offering generic or specialised services and business models

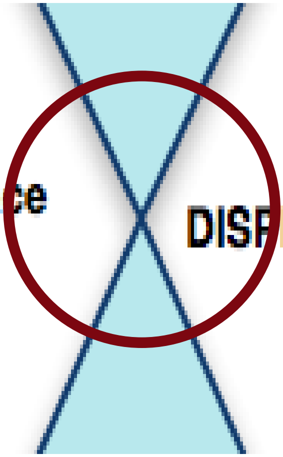
The DISPEL Hourglass

Many process representations

Many working practices

Gateway interface

one model



DISPEL ca

and abstract machine

The main focus of this talk

DISPEL enables loosely coupling

- Domain Experts

  Domain experts do not read and write DISPEL. They discuss parameters and graphs with Data-Intensive Analysts. They work by controlling enactments via their familiar tools: portals, spreadsheets, R, Matlab, ... *But there are Domain experts who are also Data-Intensive Analysts*! Particularly in research and academic contexts.

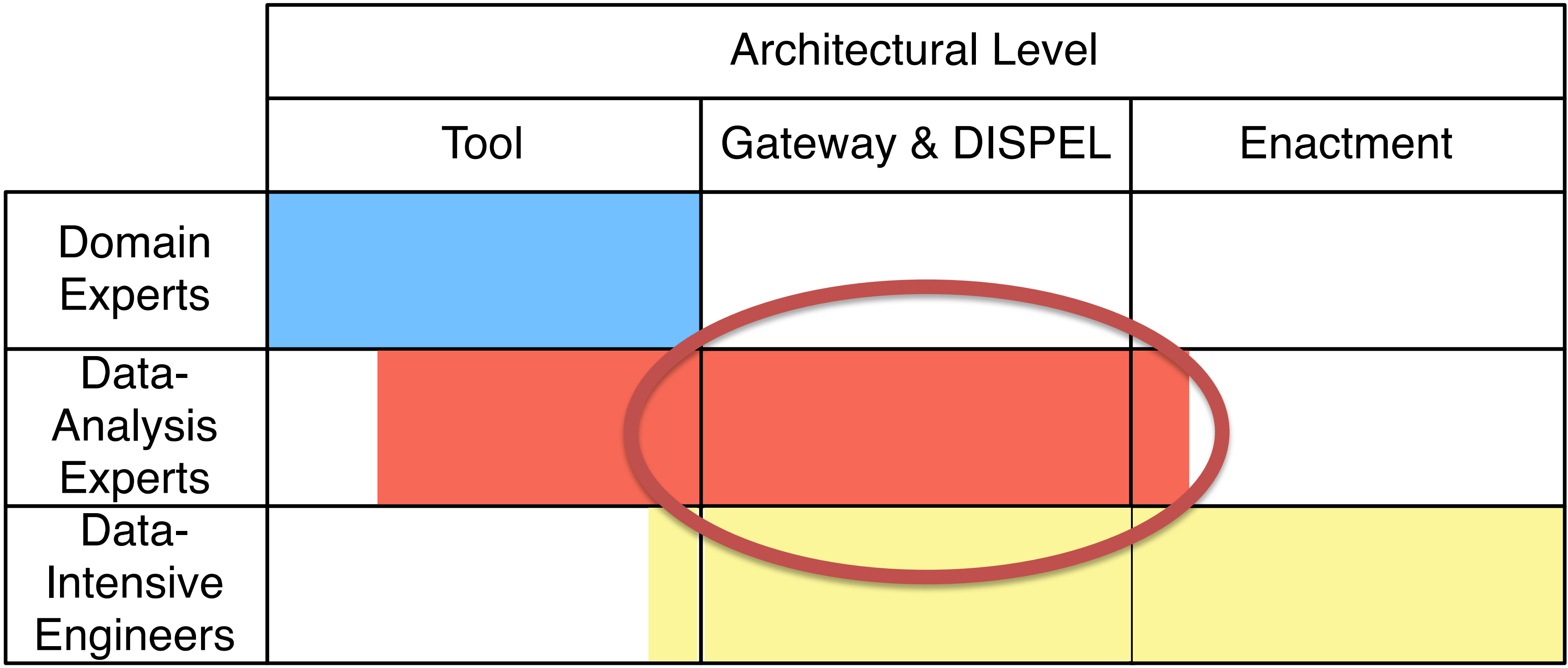
- Data-Intensive Analysts

  Data-Intensive Analysts read and write DISPEL. They are experts in data mining, text mining, image processing, time series analysis, statistics, etc. They may discuss parameters and graphs with Domain experts. They work in a familiar development environment such as Eclipse. They discuss DISPEL patterns, sentences and performance with Data-Intensive Engineers. They expect robust enactment and effective optimisation.

- Data-Intensive Engineers

  Data-Intensive Engineers read and write DISPEL, and build data-intensive platforms. They rarely meet Domain Experts. They are committed to improving all stages of DISPEL processing. They talk with Data-Intensive Analysts to help them do their work and to better understand requirements and workloads.

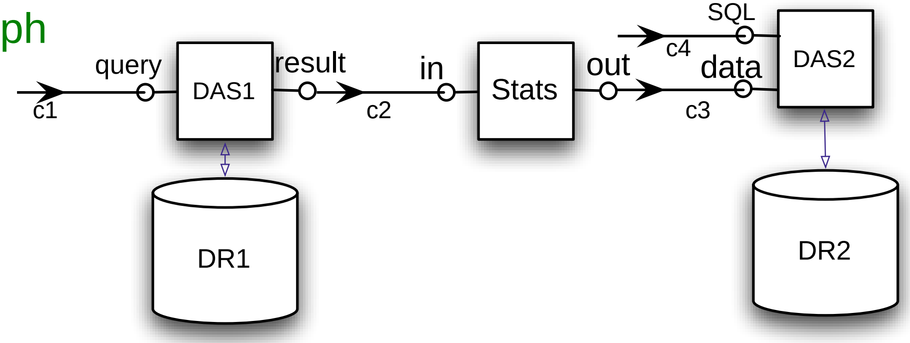
Separation of concerns



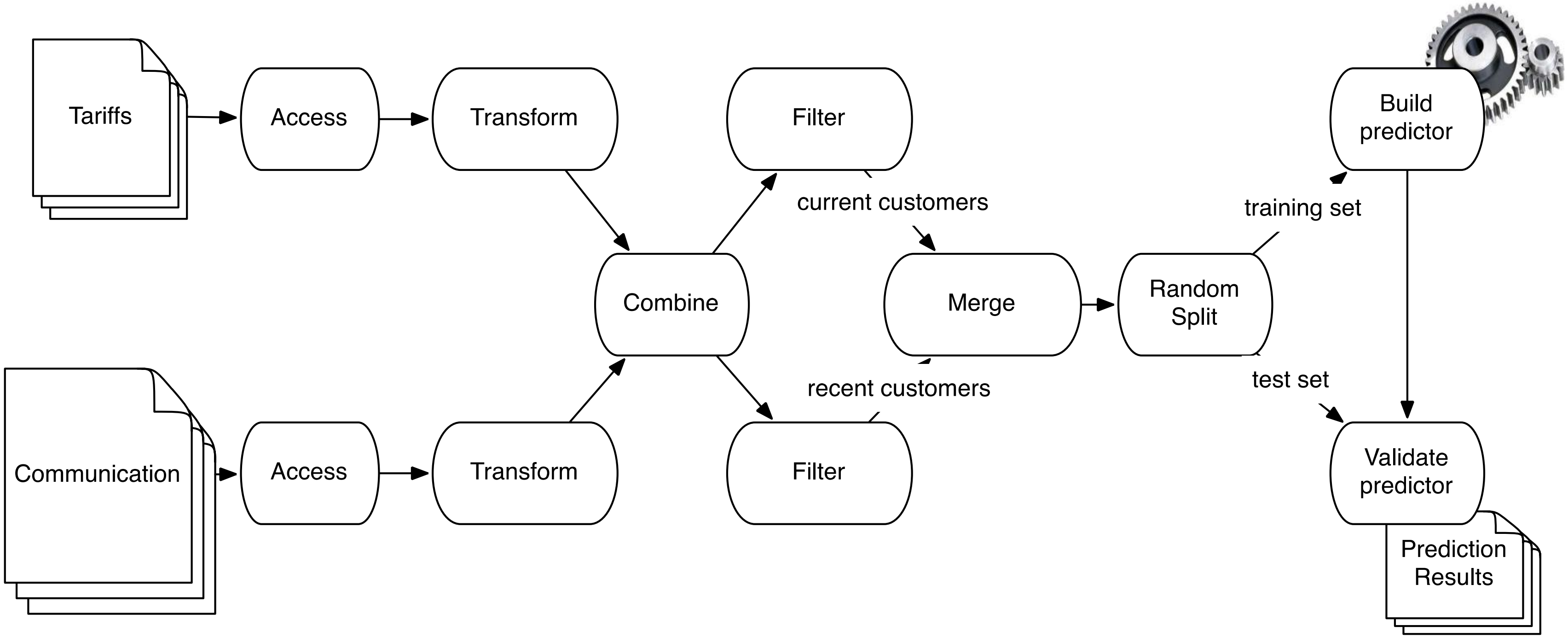
	Architectural Level		
	Tool	Gateway & DISPEL	Enactment
Domain Experts	🟦		
Data-Analysis Experts	🟥	🟥	🟥
Data-Intensive Engineers	🟨	🟨	🟨

DISPEL: an example…

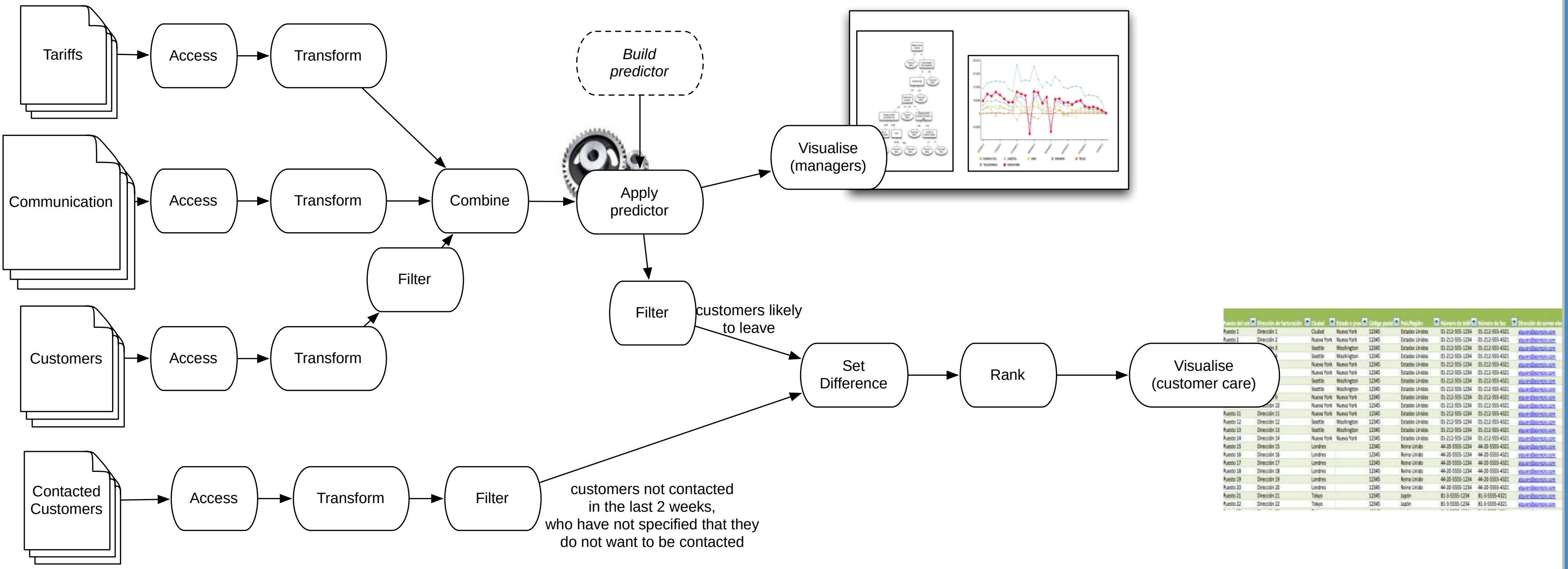
```
use admire.dataAccess.relational.DAS1; // Get definition of DAS1
use admire.transforms.statistical.Stats;   // Get definition of Stats
use admire.dataAccess.relational.DAS2; // Get definition of DAS2

String q1 = “SELECT * FROM db.table1”;  // Define literals
String q2 = “SELECT * FROM db.table2”;
String update = “INSERT ? INTO db2.columnStatistics”;

DAS1 das1 = new DAS1;  // Create PEs
Stats stats = new Stats;
DAS2 das2 = new DAS2;

|- q1; q2 -| => das1.query;  // Create graph
das1.result => stats.in;
stats.out => das2.data;
|- update; update -| => das2.SQL;
```



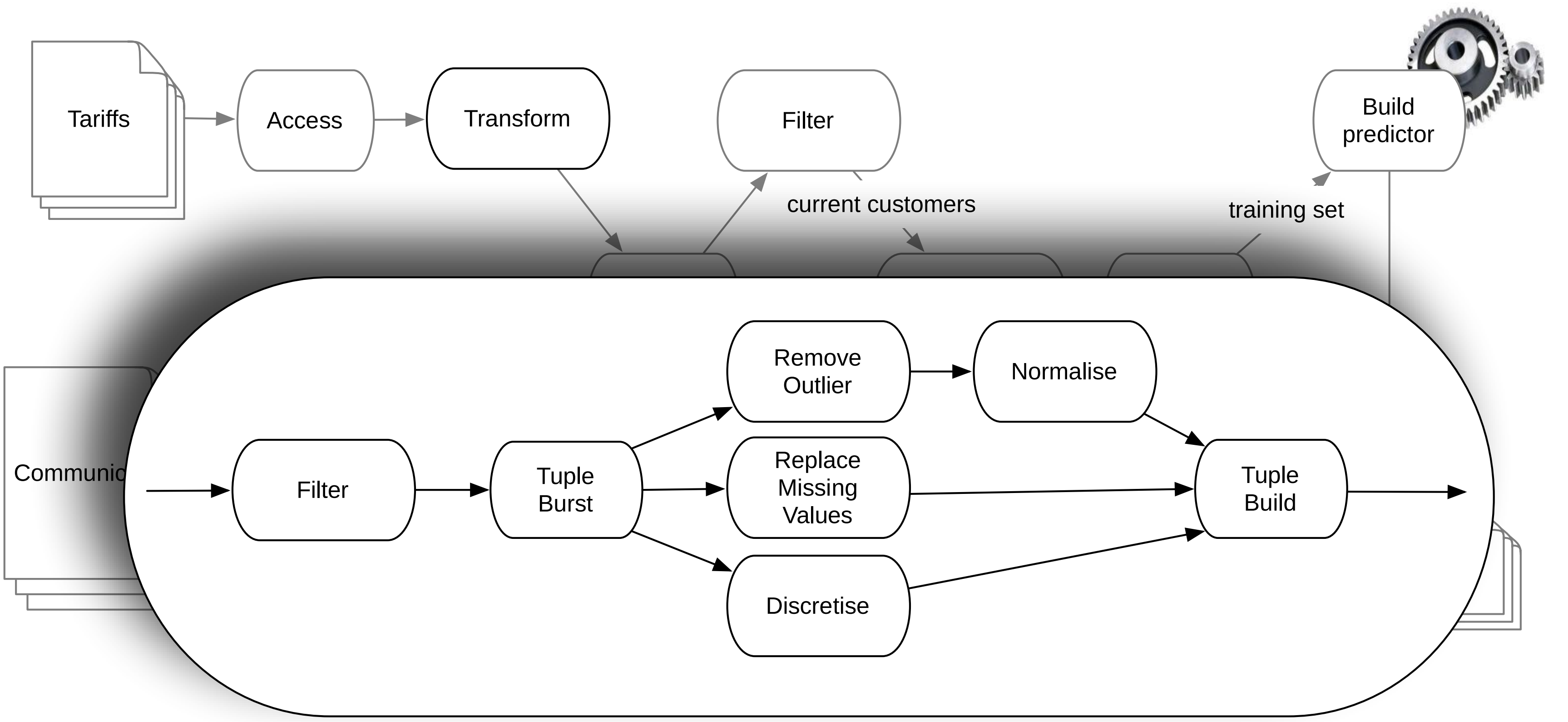
Data-Intensive Analysts. Model Building



Data-Intensive Analysts. Model Deployment



Data-Intensive Analysts. Lower-level of Details



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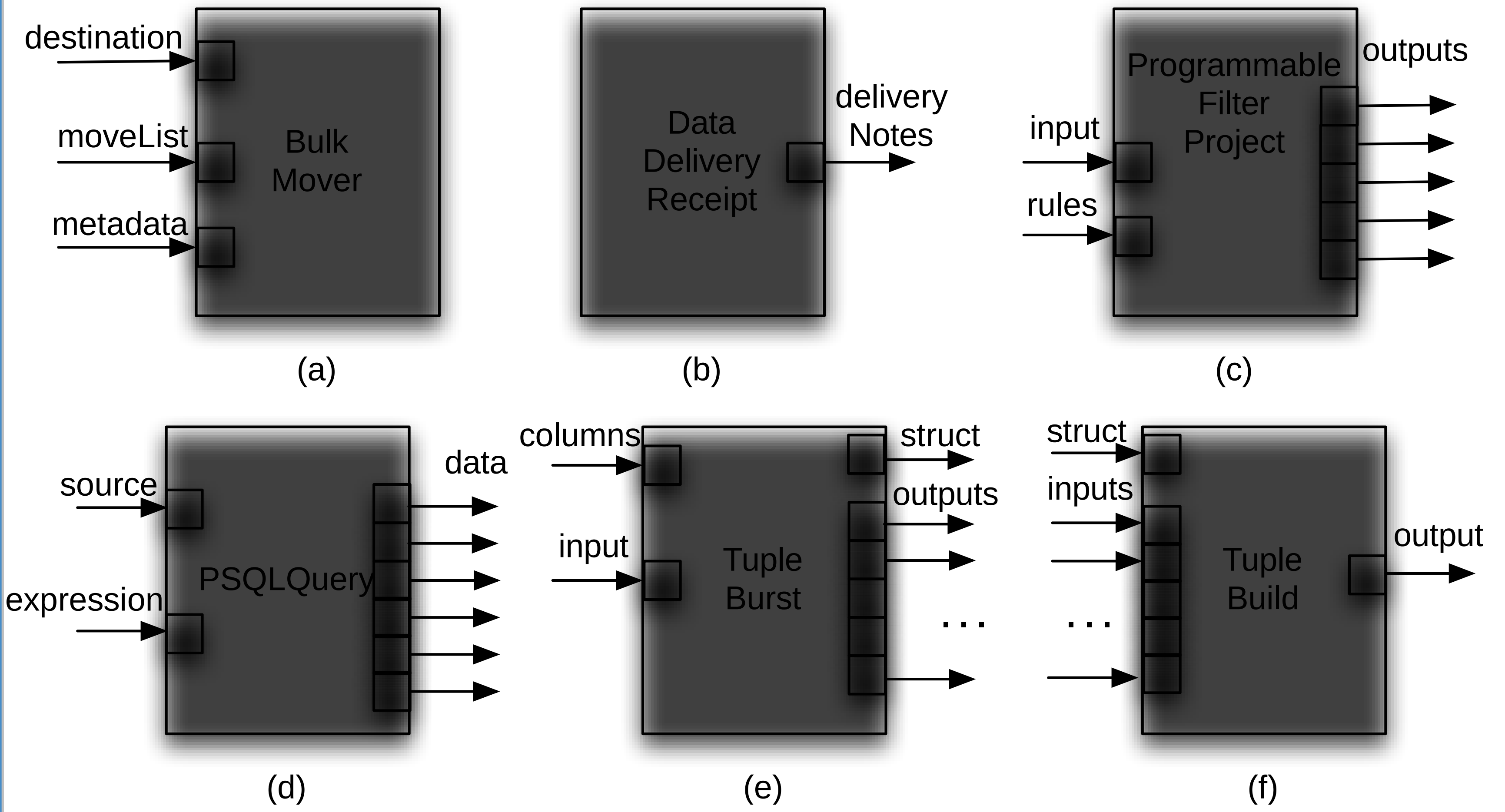
Processing Elements

- User-defined functions
  - encapsulating a data transforming algorithm
- PE descriptions
  - A unique name
  - A short definition of what they do
  - A precise description of their input and output streams
    - a structure of **Connections**
  - A precise description of their iterative behaviour
  - A precise description of their termination and error reporting
  - The (S&D)type propagation rules from inputs to outputs
  - A precise description of their properties that may permit or limit optimisation
  - Their known subtype hierarchy

Processing Elements



Processing Element Instan

- PEs are instantiated before they are use enactment
  - **new** PE_expression
- There may be many instances of a given PE
  - Think PE is a class
  - PEI is an instance of that class
- Assertions may refine the properties of a PE instance
  - **new** SQLquery **with** data **as** :[<Integer i, j; Real r; String s>]

Stating the structural type of this particular instance's result; the programmer knows the query and schema it will be used with.

Connections

- Connections carry a stream of data
  - from a PE instance to a PE instance
  - 1 source => multiple receivers
- Typically a PE processes one element of the stream at a time
- These elements are as small as makes computational sense
  - a tuple
  - a row of a matrix
- The system is responsible for buffering and optimising their flow
  - pass by reference when possible
  - serialised and compressed for long-haul data movement
  - only buffer to disk when requested or buffer spill unavoidable

Connections

- Two types describe the values passed
  - structural type (**Stype**)
    - the format / representation of the elemental value
  - domain type (**Dtype**)
    - the `meaning' of the elemental value
- Connections may have finite or continuous streams
  - Stream end, **EoS,** indicates no more data available
    - A PE transmits **EoS** when it has no more data to send
  - A connection may transmit a "no more" message from receiver to source
- Receiver **discard** throws away data
  - it sends a "no more" message immediately
- Stream literals have the form
  - |- expression -|

PE Termination

- The *default* termination behaviour occurs when either all the inputs are exhausted or all the receivers of outputs have indicated they do not want more data
  - When all of a PE's inputs have received **EoS**
    - a PE completes the use of its current data
    - then sends an EoS on all of its outputs
    - then stops
  - When all of a PE's outputs have received a "no more
    - a PE sends a "no more" on all of its inputs
    - then stops
- Termination should propagate across a distribute na
  - there may be a **stop** operation & external event as well

This is the default, a PE may stop when a particular stream delivers EoS

This is the default, a PE may stop when a particular stream receives "no more"

Language types

```
package eu.admire{
  Type ConverterPE is PE(
    <Connection:Any::Thing input>  =>
    <Connection:Any::Thing output>  );
  Type Combiner is PE(
    <Connection[ ] inputs> =>
    <Connection output>  );
  Type ErrorStream is Connection:
             < error:String::”lang:ErrorMessage”; culprit >;
  Type ProgrammableCombiner is PE(
   <Connection[] inputs;
    Connection:String::”lang:JavascriptCode” controlExpression> =>
   <Connection output;
    ErrorStream errors >  );

  register ConverterPE, Combiner, ErrorStream, ProgrammableCombiner;}
```

PEs as subtypes of PEs

```
package eu.admire{  use eu.admire.Combiner;
  use eu.admire.ProgrammableCombiner;

  Type SymmetricCombiner is Combiner with inputs permutable;
  Type SymmetricProgrammableCombiner is ProgrammableCombiner
    with inputs permutable;

  register SymmetricCombiner, SymmetricGenericCombiner;}
```

Indicate order of inputs is not significant

Make these new PE types subtypes of the previously declared types.

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Stypes and Dtypes

```
package coral.reef.ecology{

  Stype Image is Pixel[ ][ ];
  Stype Camera is <Integer cNumber; String cType; Real x, y, z, theta, phi, alpha,
                aperture, magnification, frequency; Real[ ] settings; rest >;
  Stype Illuminator is <Integer iNumber; String iType; Real x, y, z, theta, phi,
                beamWidth, intensity, iFrequency, duration; Real[ ] iSettings; rest >;
  Stype Frame is <Time t; Image[ ] images; Camera[ ] cameras;
                         Illuminator[ ] lighting>;
  register Image, Camera, Illuminator, Frame;
  }
```

Stypes and Dtypes

```
package coral.reef.ecology{
 namespace cre “Coral_Reef_Ecology.observingStation.terms:”;
 use coral.reef.ecology.Frame;
 Stype Object is <Real x, y, z, radius>;
 Stype ObjectMap is <Frame:: cre:Primary_PIV_data frame;
                     Object[ ]:: cre:Putative_Individuals objects>;

  Type ObjectRecogniser is PE (
    <Connection: Frame:: cre:PrimaryPIVdata frames> =>
    <Connection: ObjectMap:: cre:First_Reconstruction putativeIndividuals>
  );
 register Object, ObjectMap, ObjectRecogniser;}
```

Stypes and Dtypes

```
package coral.reef.ecology{
 namespace cre “Coral_Reef_Ecology.observingStation.terms:”;
 use coral.reef.ecology.ObjectMap;
 Stype Individual is <Object:: cre:Individual_Subject confirmeIndividual;
                      Integer:: cre:Unique_Arbitrary_Tag idNumber;
                      String:: cre:Species_Or_Inert taxa; Boolean swimmer;
                      Real:: cre:Mass_Estimate1_Kilograms mass>;
 Stype IndividualMap is <Frame:: cre:Primary_PIV_data frame;
                          Individual[ ]:: cre:Confirmed_Individuals individuals>;

  Type IndividualRecogniser is PE (
    <Connection: ObjectMap:: cre: First_Reconstruction putativeIndividuals
    > =>
    <Connection: IndividualMap:: cre:Second_Reconstruction taggedIndividuals
    >
  );
 register Individual, IndividualMap, IndividualRecogniser;}
```

Stypes and Dtypes

```
package coral.reef.ecology{
 namespace cre “Coral_Reef_Ecology.observingStation.terms:”;
 use coral.reef.ecology.IndividualMap;
 Stype MovingIndividual is <Individual:: cre:Tagged_Subject confirmeIndividual;
                            Real[ ]:: cre:Meters_Per_Second[ ] velocity;
                            Real:: cre:Joules kineticEnergy>;
 Stype MovementMap is <Frame:: cre:Primary_PIV_data frame;
                       MovingIndividual[ ]:: cre:Moving_Individuals individuals>;

  Type MovementRecogniser is PE (
    <Connection: IndividualMap:: cre:Second_Reconstruction taggedIndividuals
    > =>
    <Connection: MovementMap:: cre:Third_Reconstruction movingIndividuals
    >
  );
 register MovingIndividual, MovementMap, MovementRecogniser;}
```

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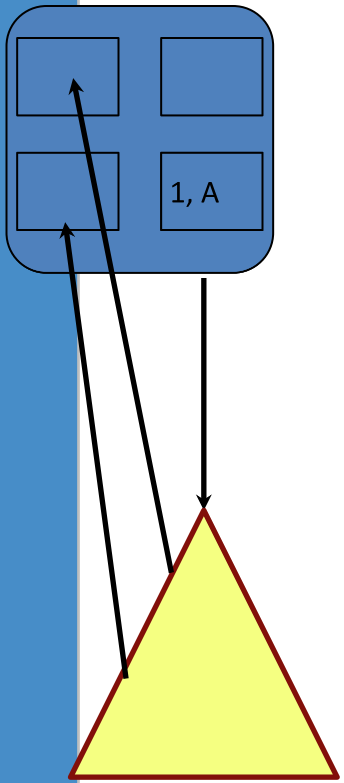
Coupling portlet to DISPEL function



Step 1: user inputs solicited values

Step 2: portal system validates values

Step 3: portal system constructs DISPEL sentence with these values as parameters of a provided function

Step 4: portal system sends DISPEL sentence to gateway

Steps 5 to n: gateway and systems behind it validate and enact the sentence

Step n+1: gateway sends summary/partial results to progress viewer

Step n+m: gateway sends final (summary) results to result viewer

The function that is called

```
package eu.admire.seismology{  use
eu.admire.seismology.proj1portlet4invokeCorrelations;
 use eu.admire.Time;
 Time startTime = <year=1996, day = 53, seconds = 0>;
 Time endTime = <year=1996, day = 54, seconds = 0>;
 Real minFreq = 0.01; //frequencies considered in Hertz
 Real maxFreq = 1.0;
 Real maxOffset = 10*60*60;

 proj1portlet4invokeCorrelations(
                    startTime, endTime, minFreq, maxFreq, maxOffset );}
```

Values solicited from user and inserted into a minimal template; some of these could equally well be `constants' embedded as hidden defaults in the template

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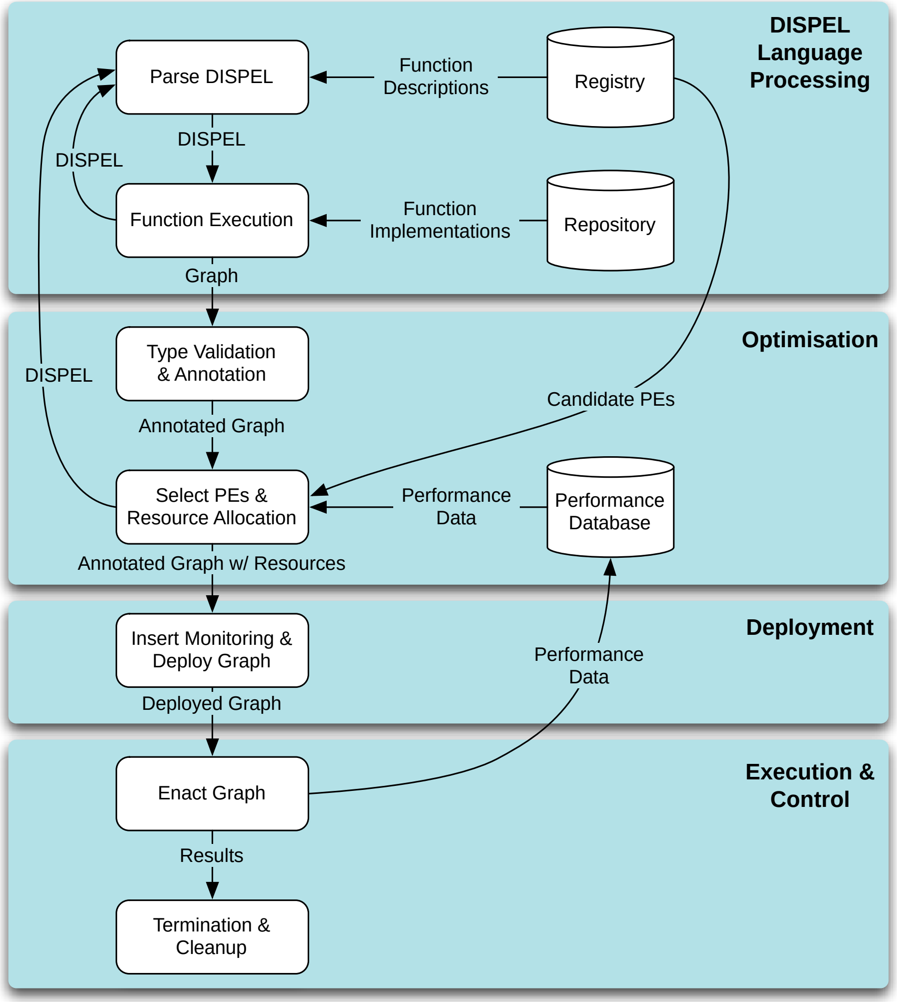
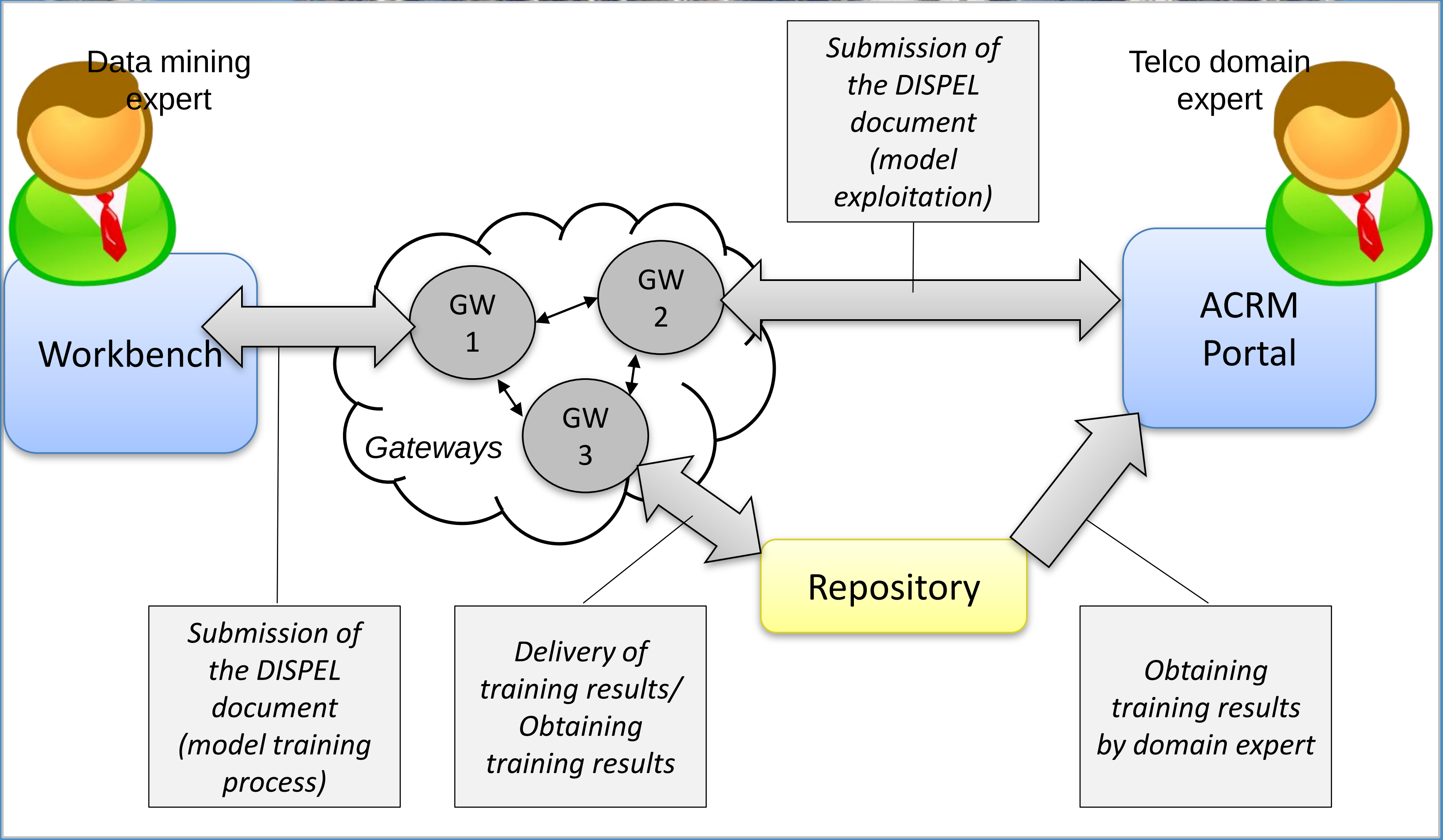
DISPEL evaluation



- A DISPEL sentence is prepared…
- Sent to a gateway…
  - which may inspect it and the sender’s credentials
  - and then accept it and initiate enactment
- Enacted in four phases
  - DISPEL language processing
    - to produce a graph and/or register definitions
  - Optimisation
  - Deployment
    - across hosting platforms
  - Execution and control
    - including termination and tidying

Architecture (e.g., ACRM)



Submission of the DISPEL document (model exploitation)

Submission of the DISPEL document (model training process)

Delivery of training results/ Obtaining training results

Obtaining training results by domain expert

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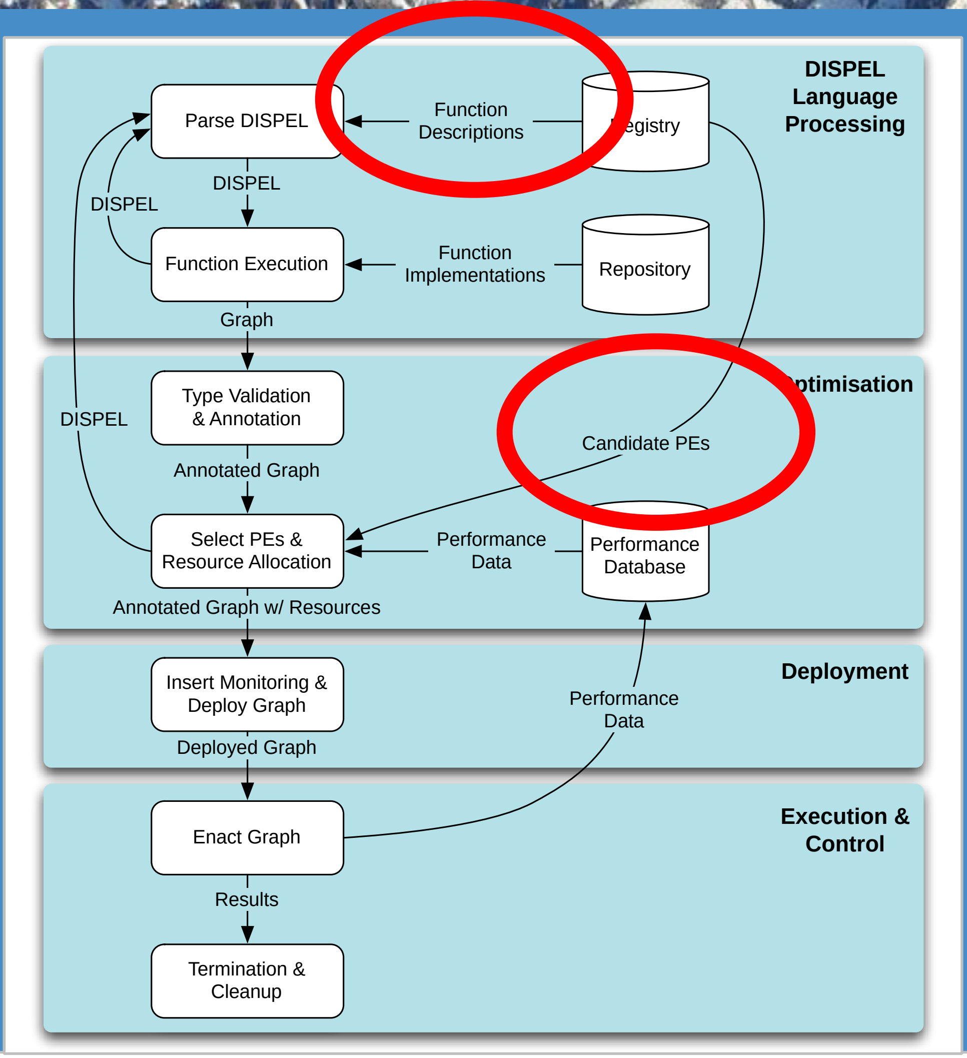
The DISPEL Registry

- “Making the hourglass bottleneck narrower”
- Allowing DISPEL code to be “smaller”, while still generating large graphs
  - By means of describing patterns
    - Functions and composite PEs
  - …with rich semantics
    - Core ontology for these descriptions
    - Domain-specific ontologies can be incorporated
  - …plus human-focused descriptions (since domain experts must understand them)
    - Dublin core properties, social discussion, etc.

Semantics in DISPEL processing

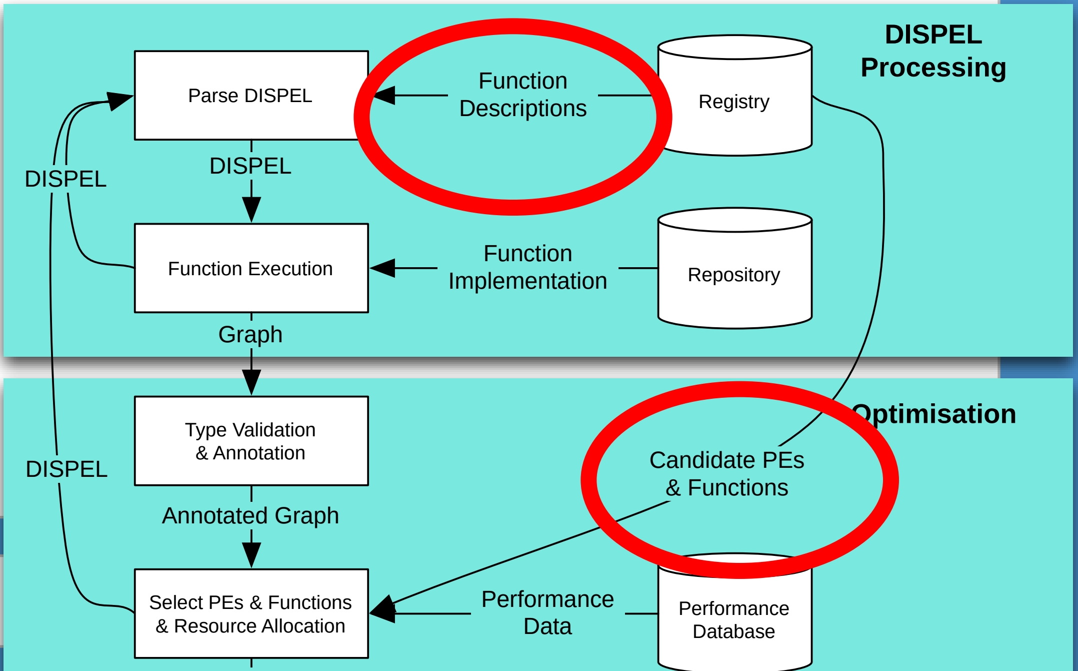


Registry Contents

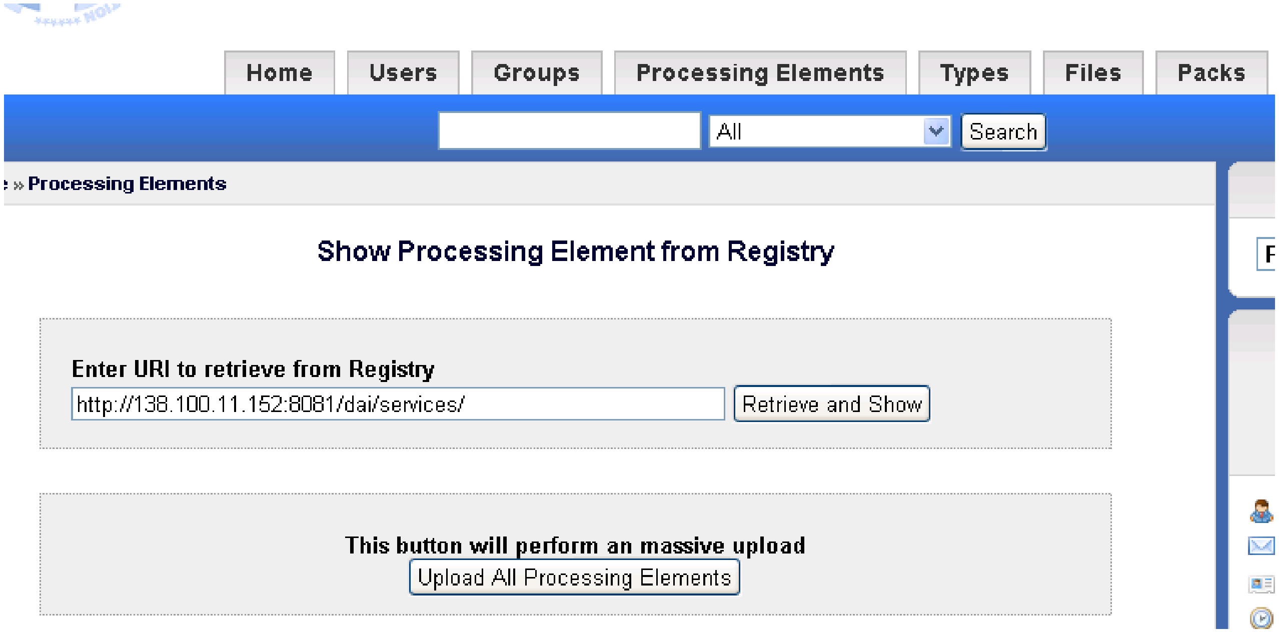
- Initial library of 81 domain-dependent and independent Processing Elements
  - – DISPEL PE library initialisation file
    - Many PEs inherited from OGSA-DAI activities
    - Incorporating PEs from ADMIRE use cases
- Open distributed registration of new domain-specific (or generic) PEs to start soon
  - – Sorting out the social networking part

Advanced Functionalities

- Find candidate PEs and functions
  - Find “similar” PEs
    - Queries for sibling PEs in the ontology hierarchy
  - Find “compatible” and “functionally-equivalent” PEs and functions if explicitly-defined in the ontology
  - Infer “compatible” PEs and functions



Reusing the myExperiment frontend



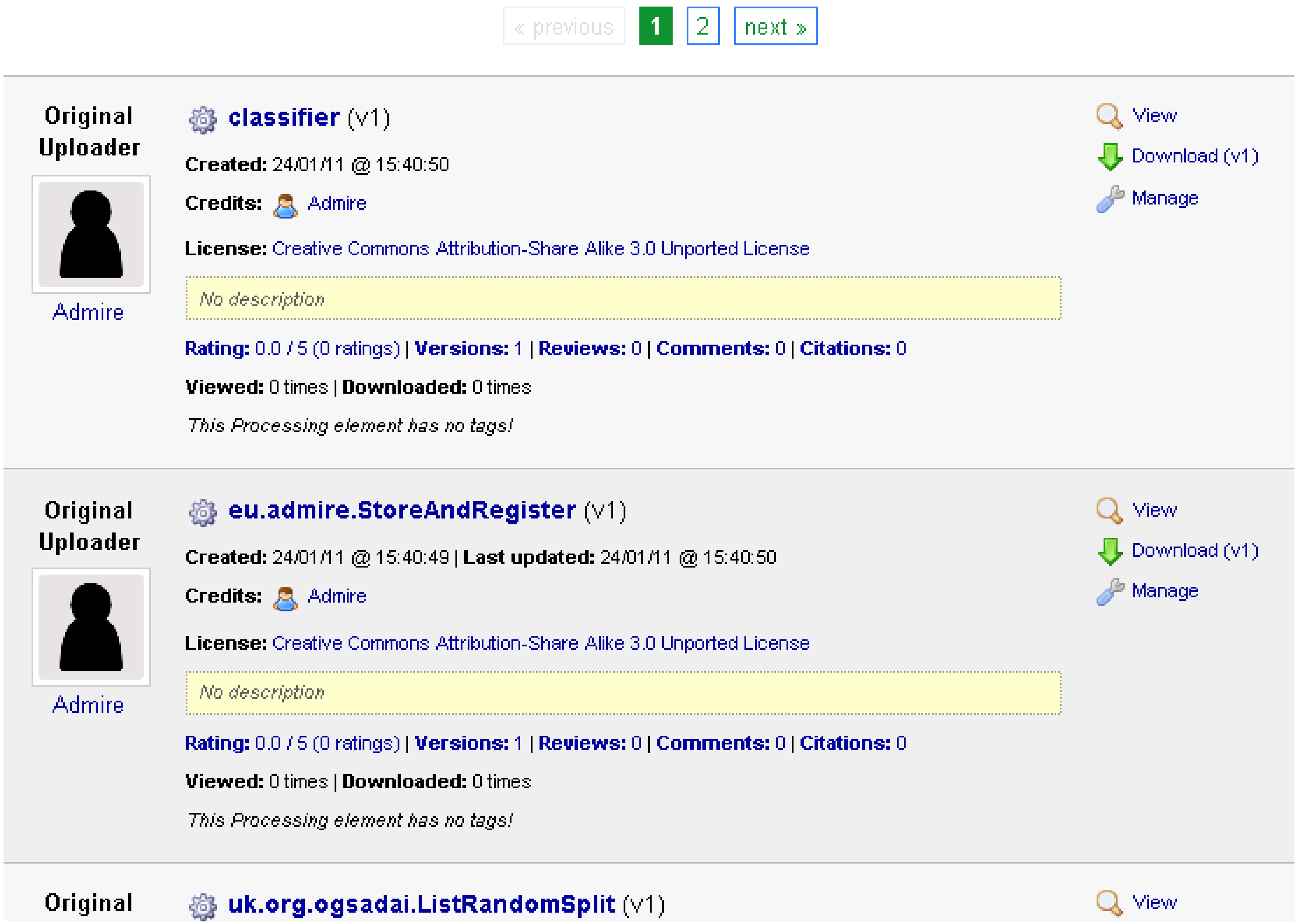
Show Processing Element from Registry

Enter URI to retrieve from Registry

http://138.100.11.152:8081/dai/services/

This button will perform an massive upload

Example of a PE list



« previous **1** 2 next »

Original Uploader

Admire

classifier (v1)

Created: 24/01/11 @ 15:40:50

Credits: Admire

License: Creative Commons Attribution-Share Alike 3.0 Unported License

No description

Rating: 0.0 / 5 (0 ratings) | **Versions:** 1 | **Reviews:** 0 | **Comments:** 0 | **Citations:** 0

Viewed: 0 times | **Downloaded:** 0 times

This Processing element has no tags!

Original Uploader

Admire

eu.admire.StoreAndRegister (v1)

Created: 24/01/11 @ 15:40:49 | **Last updated:** 24/01/11 @ 15:40:50

Credits: Admire

License: Creative Commons Attribution-Share Alike 3.0 Unported License

No description

Rating: 0.0 / 5 (0 ratings) | **Versions:** 1 | **Reviews:** 0 | **Comments:** 0 | **Citations:** 0

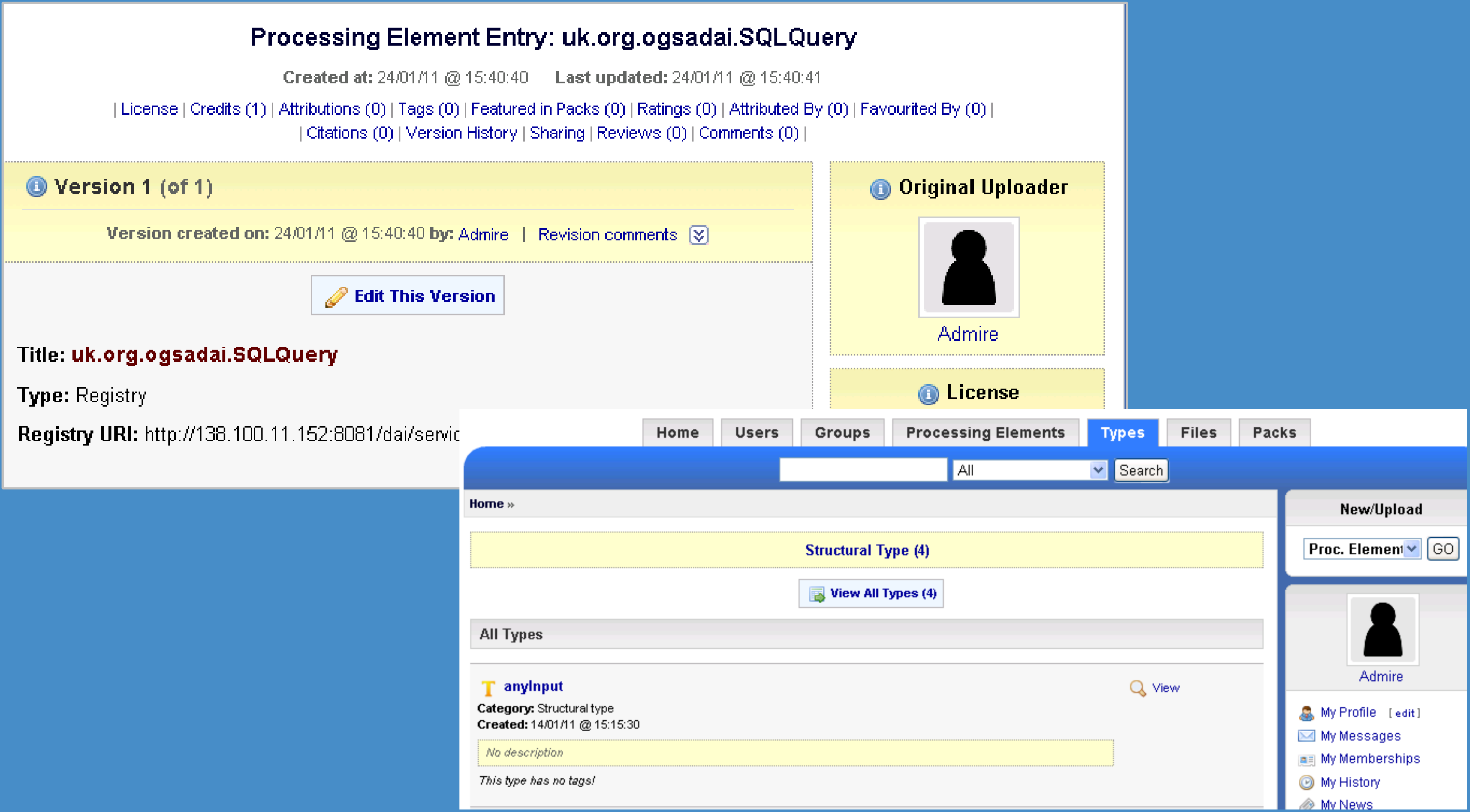
Viewed: 0 times | **Downloaded:** 0 times

This Processing element has no tags!

Original

uk.org.ogsadai.ListRandomSplit (v1)

Example of a structural type



Processing Element Entry: uk.org.ogsadai.SQLQuery

Created at: 24/01/11 @ 15:40:40 **Last updated:** 24/01/11 @ 15:40:41

| License | Credits (1) | Attributions (0) | Tags (0) | Featured in Packs (0) | Ratings (0) | Attributed By (0) | Favourited By (0) |
| Citations (0) | Version History | Sharing | Reviews (0) | Comments (0) |

Version 1 (of 1)

Version created on: 24/01/11 @ 15:40:40 **by:** Admire | Revision comments

Edit This Version

Title: uk.org.ogsadai.SQLQuery

Type: Registry

Registry URI: http://138.100.11.152:8081/dai/servic

Original Uploader

Admire

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Home »

Structural Type (4)

View All Types (4)

All Types

anyInput

View

Category: Structural type

Created: 14/01/11 @ 15:15:30

No description

This type has no tags!

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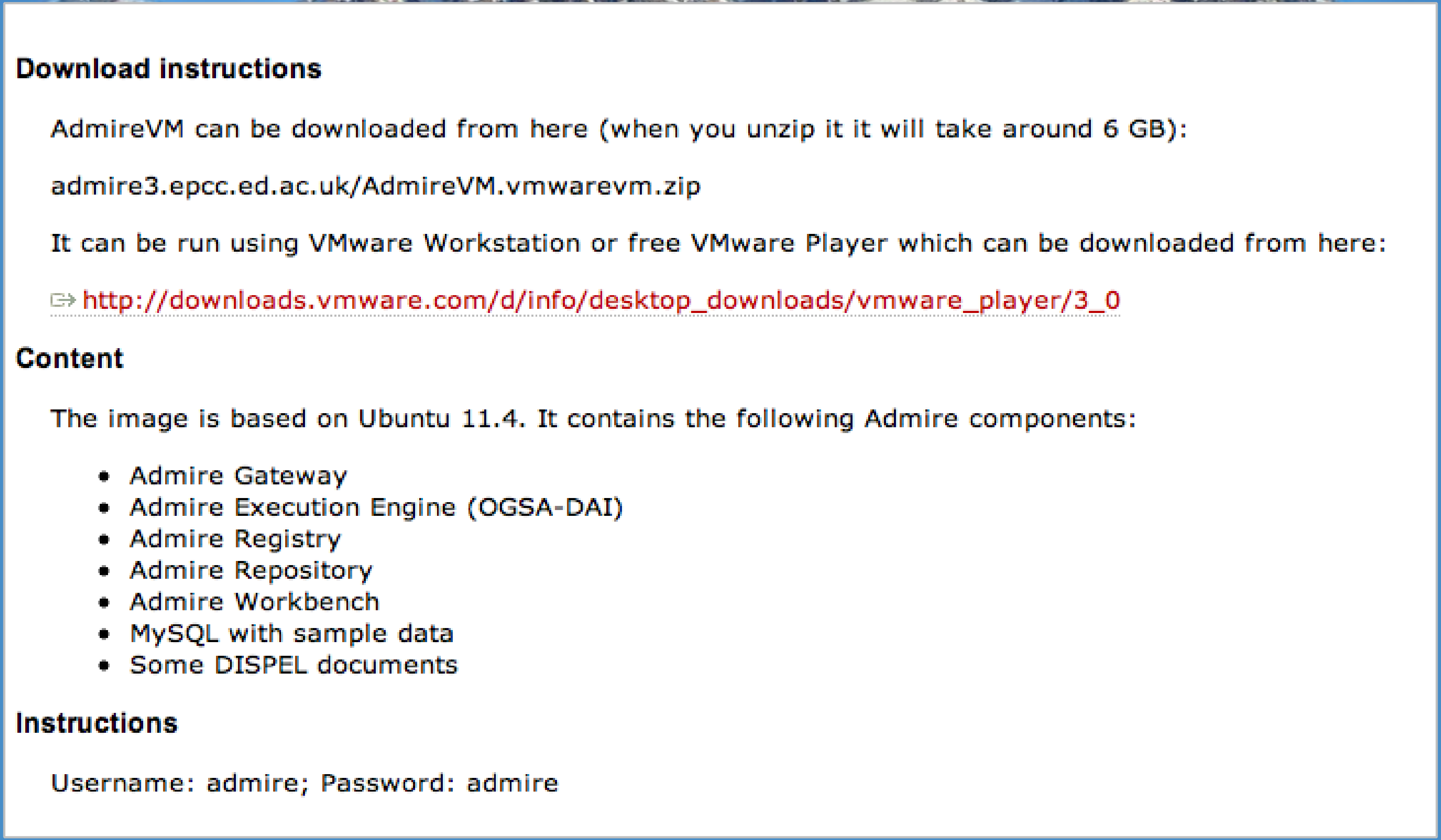
DISPEL resources



Download instructions

AdmireVM can be downloaded from here (when you unzip it it will take around 6 GB):

admire3.epcc.ed.ac.uk/AdmireVM.vmwarevm.zip

It can be run using VMware Workstation or free VMware Player which can be downloaded from here:

http://downloads.vmware.com/d/info/desktop_downloads/vmware_player/3_0

Content

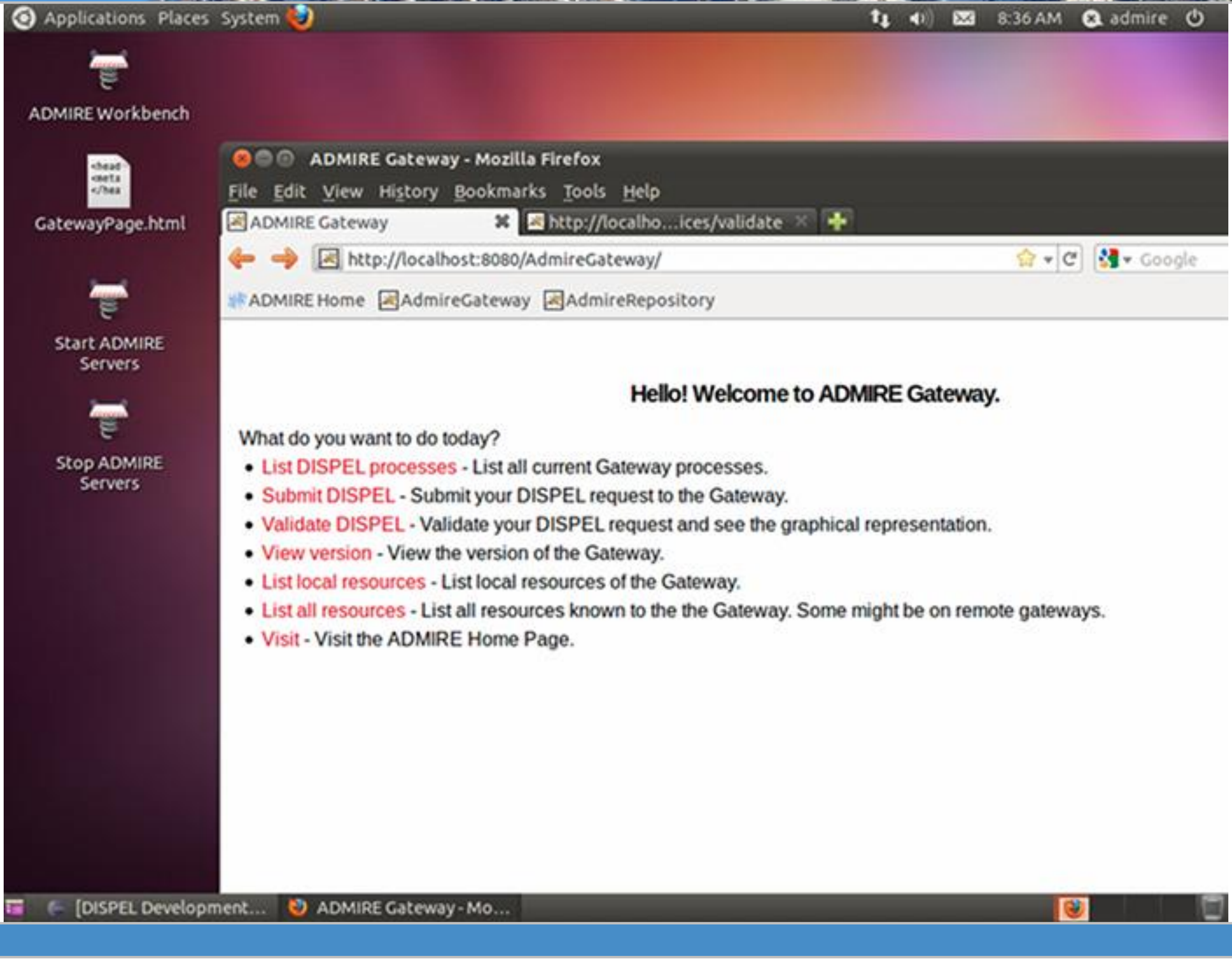
The image is based on Ubuntu 11.4. It contains the following Admire components:

- Admire Gateway
- Admire Execution Engine (OGSA-DAI)
- Admire Registry
- Admire Repository
- Admire Workbench
- MySQL with sample data
- Some DISPEL documents

Instructions

Username: admire; Password: admire

DISPEL resources



Hello! Welcome to ADMIRE Gateway.

What do you want to do today?

- List DISPEL processes - List all current Gateway processes.
- Submit DISPEL - Submit your DISPEL request to the Gateway.
- Validate DISPEL - Validate your DISPEL request and see the graphical representation.
- View version - View the version of the Gateway.
- List local resources - List local resources of the Gateway.
- List all resources - List all resources known to the the Gateway. Some might be on remote gateways.
- Visit - Visit the ADMIRE Home Page.

Data-Intensive Research with DISPEL

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Ontology Engineering Group
Universidad Politécnica de Madrid

(in collaboration with all the ADMIRE project consortium)
Special thanks to Malcolm Atkinson, from whom most of the slides have been reused