Algorithms and Architecture for Managing Evolving ETL Workflows

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Outline

- Introduction
- Problem Statement
- Project Objectives
- ETL Modelling
  - BPMN4ETL
  - Extended Relational Algebra
  - Experiments
  - BEXF (XML Interchange format)
- ETL Evolution
  - Current Approaches
  - Our Approach
- Conclusion

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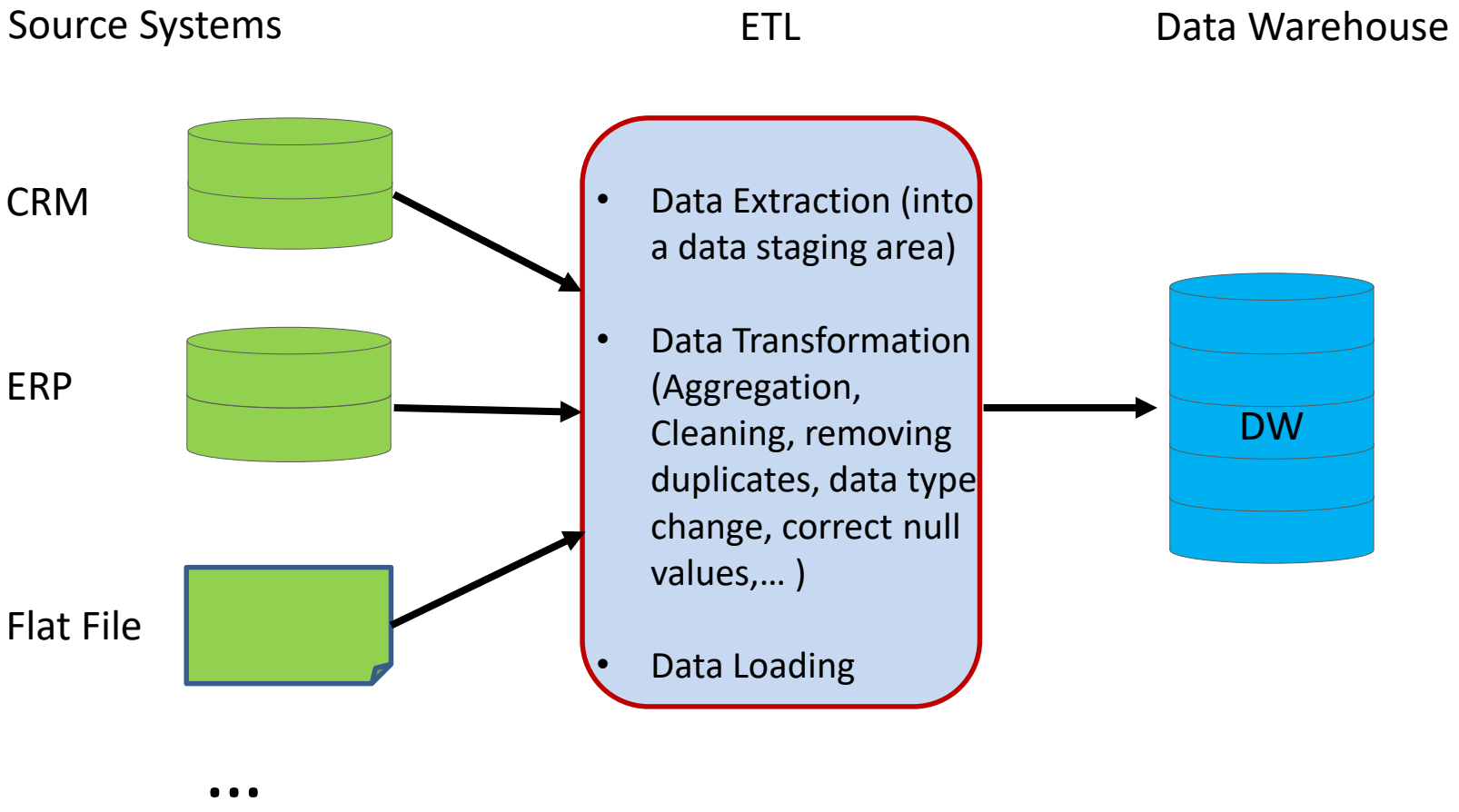
Introduction

Extract-Transform-Load (ETL)



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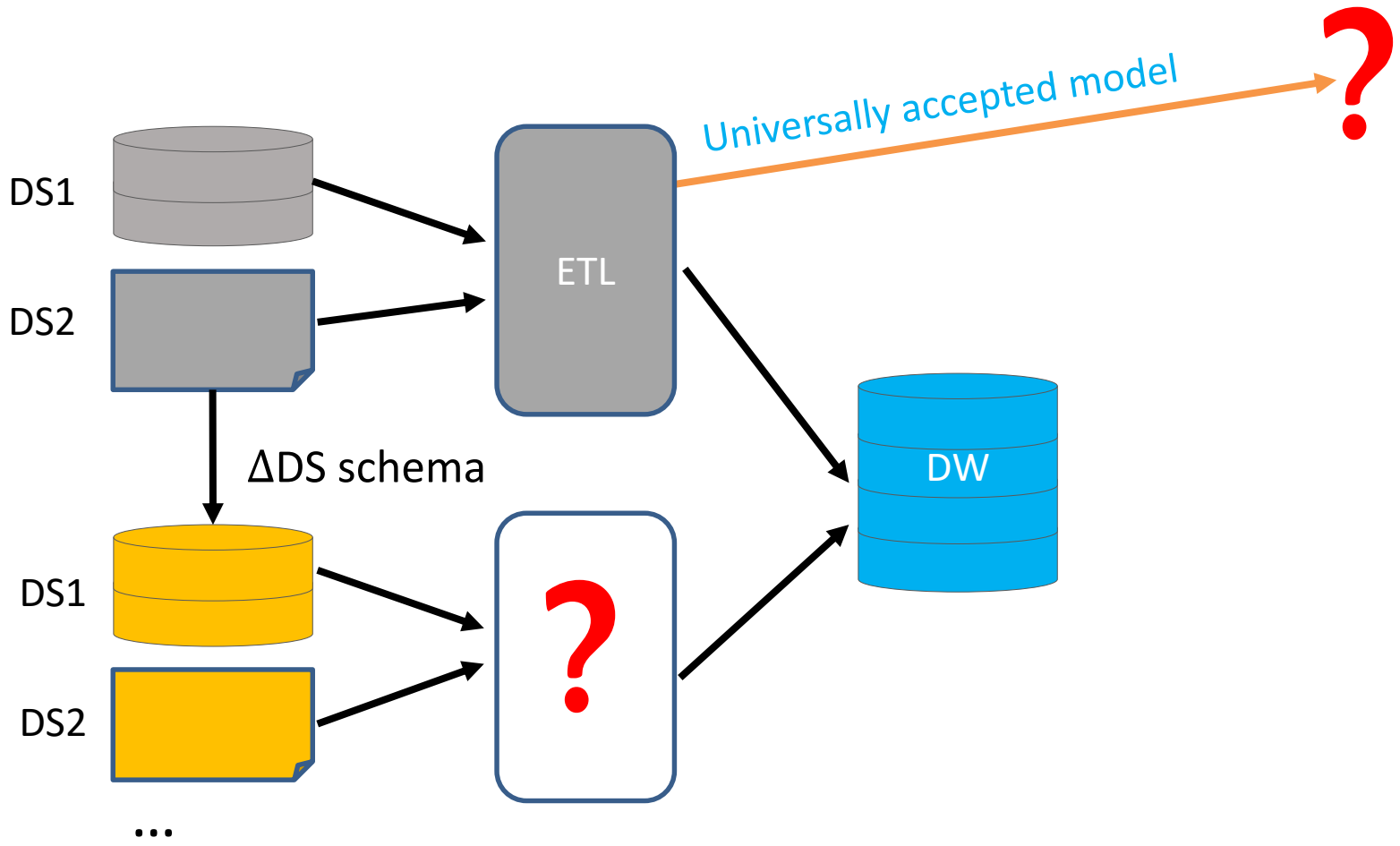
Problem Statement



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Objectives

1. To propose a methodology for designing ETL processes that will facilitate a smooth transition from gathering user requirements to the actual implementation. This methodology will include all aspects of ETL design, from conceptual modelling to physical implementation

2. To develop a framework to (semi-) automatically repair ETL workflows upon data source changes

Currently focusing on relational data

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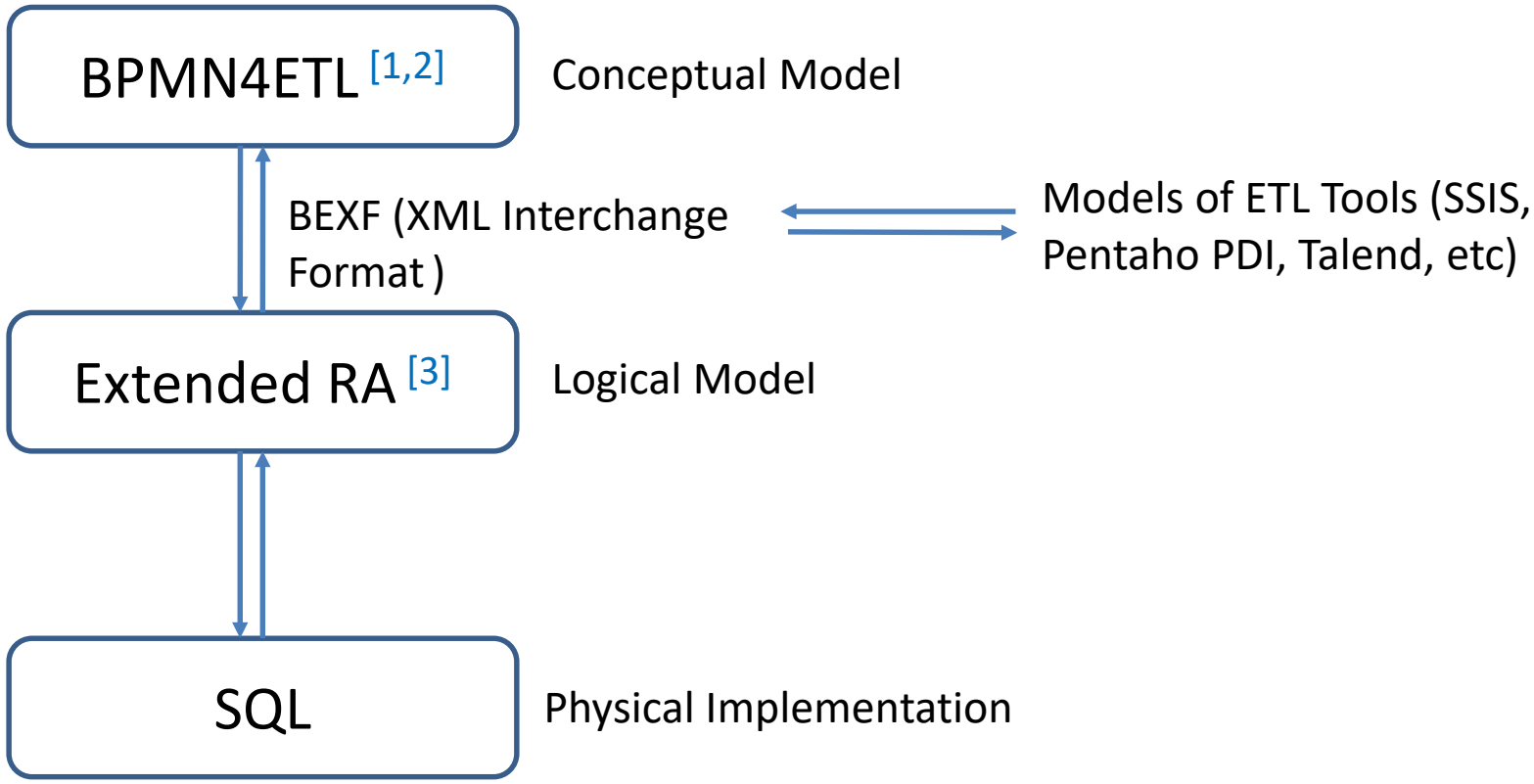
ETL Modelling (Our approach)



ETL Modelling

Scenario

The historical ETL load of DimBroker Dimension of TPC-DI [6] Dataset

	ATTRIBUTES
HR.csv	EmployeeID, ManagerID, EmployeeJobCode, EmployeeFirstName… , EmployeePhone
DimDate	SK_DateID, DateValue, CalendarYearDesc,…, HolidayFlag
DimBroker	Sk_BrokerID, BrokerID, ManagerID, FirstName,…,IsCurrent, BatchID, EffectiveDate, EndDate

Transformations

- Records where **EmployeeJobCode** is not **314** are not broker records, and are ignored (Filter)
- **SK_BrokerID** is set appropriately for new records (Surrogate key assignment)
- **IsCurrent** is set to true
- **EffectiveDate** is set to the earliest date in the **DimDate** table and **EndDate** is set to **9999-12-31** (Aggregate)
- **BatchID** is set as described in TPC-DI specification document

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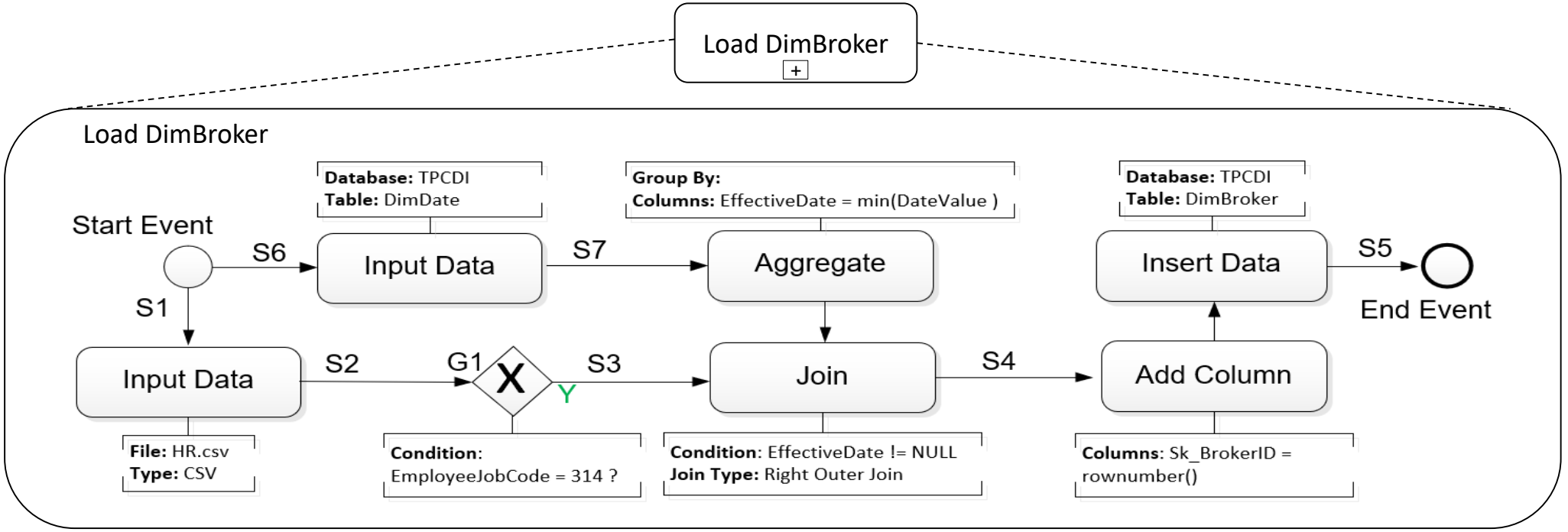
BPMN4ETL: Conceptual modelling [1,2]



- BPMN is a standard modelling language and can be used for documentation
- Models both control and data flow
- ETL activities (e.g., aggregations, conversions, etc) can be plugged in easily
- Less complex because user is not overwhelmed with inter-attribute mappings
- Easy communication and validation between an Operational Database Designer, an ETL Designer and a BI analyst
- Exposes the manipulation of data and their order from one ETL task to the other
- Can be translated directly to relational algebra, SQL, or an XML interchange format

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Logical Modelling : Extended Relational Algebra [3]

Operator	Notation
Selection	$\sigma_C(R)$
Projection	$\pi_{A_1,..,A_n}(R)$
Cartesian Product	$R_1 \times R_2$
Union	$R_1 \cup R_2$
Intersection	$R_1 \cap R_2$
Difference	$R_1 - R_2$
Join	$R_1 \bowtie_C R_2$
Natural Join	$R_1 * R_2$
Left Outer Join	$R_1 ⟕_C R_2$
Right Outer Join	$R_1 ⟖_C R_2$
Full Outer Join	$R_1 ⟗_C R_2$
Semijoin	$R_1 \ltimes_C R_2$
Division	$R_1 \div R_2$

Operator	Notation
Aggregate	$\mathcal{A}_{A_1,..,A_m \mid C_1=\mathsf{F}_1(B_1),..,C_n=\mathsf{F}_n(B_n)}(R)$
Delete	$R \leftarrow R - \sigma_C(R)$
Extend	$\mathcal{E}_{A_1=\mathsf{Expr}_1,\ldots,A_n=\mathsf{Expr}_n}(R)$
Input	$R \leftarrow \mathcal{I}_{A_1,\ldots,A_n}(F)$
Insert	$R \leftarrow R \cup S$ or $R \leftarrow S$
Lookup	$R \leftarrow \pi_{A_1,\ldots A_n}(R_1 \bowtie_C R_2)$
Remove duplicates	$\delta(R)$
Rename	$\rho_{A_1 \leftarrow B_1,\ldots,A_n \leftarrow B_n}(R)$ or $\rho_S(R)$
Sort	$\tau_A(R)$
Update	$\mathcal{U}_{A_1=\mathsf{Expr}_1,\ldots,A_n=\mathsf{Expr}_n \mid C}(R)$
Update Set	$R \leftarrow \mathcal{U}(R)_{A_1=\mathsf{Expr}_1,\ldots,A_n=\mathsf{Expr}_n \mid C}(S)$

Logical Modelling : Extended Relational Algebra

$$\text{TempHR} \leftarrow \mathcal{I}_{\text{EmployeeID,ManagerID,FirstName,...}}(\text{HR.csv}) \quad (1)$$

$$\text{TempDate} \leftarrow \mathcal{I}_{\text{Sk\_dateid,Datevalue,Datedesc,...}}(\text{DimDate}) \quad (2)$$

$$\text{Temp1} \leftarrow \sigma_{\text{EmployeeJobCode} = \text{'314'}}(\text{TempHR}) \quad (3)$$

$$\text{Temp2} \leftarrow \mathcal{A}_{\text{EffectiveDate=min(DateValue)}}(\text{TempDate}) \quad (4)$$

$$\text{Temp3} \leftarrow \text{Temp1} \bowtie_{\text{EffectiveDate} \neq \text{NULL}} (\text{Temp2}) \quad (5)$$

$$\text{Temp4} \leftarrow \mathcal{E}_{\text{SK\_BrokerID} = \text{rownumber()}}(\text{Temp3}) \quad (6)$$

$$\text{DimBroker} \leftarrow \text{DimBroker} \cup (\pi_{\text{SK\_BrokerID, EmployeeID,ManagerID,FirstName,...}}(\text{Temp4})) \quad (7)$$

- RA provides a set of operators that manipulates relations to ensure that there is no ambiguity
- Can also be directly translated into SQL to be executed in any Relational Database Management System (RDBMS). We avoid dealing with the peculiarities of a particular programming language
- When extended with update operations, they can provide a logical model of different ETL scenarios. E.g. Slowly changing dimension with dependencies found in the TPC-DI Benchmark

Limitation

Difficult to model certain complex tasks in relational algebra even though they can be done directly with SQLs. (E.g. window functions and loops)

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ETL Modelling (Experiments)

Experimental Evaluation

Experiments implemented in two ways:

1. Using Pentaho PDI , translating the BPMN4ETL directly into Pentaho PDI
2. Using RA , translating BPMN4ETL into extended RA, and then implementing the RA operations using Postgres PLSQL.

TPC-DI Benchmark

- Data sources are of different formats (xml, csv, txt, and so on)
- Source data model: Based on a fictitious retail brokerage firm and external sources
- Target data model: Has a snowstorm schema
- One historical load and two identical incremental loads
- Scale factor (number of records) - 3 (4.5 million), 5 (7.8 million), 10 (16.1 million)

Platform

Intel i7 computer, with a RAM of 16 GB, running the Windows 10 Enterprise operating system, using the Postgres SQL database as the DW storage

ETL Modelling (Experiments)

Performance

Execution times to complete TPC-DI benchmark Load

Time = hours:minutes:seconds

		Historical	Incremental 1	Incremental 2
SF-3	PLSQL	00:12:50	00:00:09	00:00:07
	PDI	11:23:52	00:01:32	00:01:40
SF-5	PLSQL	00:22:31	00:00:15	00:00:14
	PDI	20:25:32	00:03:03	00:03:11
SF-10	PLSQL	02:11:15	00:00:39	00:00:36
	PDI	25:08:13	00:11:35	00:12:38

Pentaho PDI Optimization

- PDI memory limit was increased from 2G to 4G
- PDI performance tuning tips were applied

- https://help.pentaho.com/Documentation/7.1/0P0/100/040/010

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ETL Modelling (XML Interchange format)

BPMN4ETL eXchange format (BEXF)

```
<ETLProcess id="_idProcess" name="Load of DimBroker">
 <StartEvent id="_idStartEvent" name="Start Event">
  <outRefId>_idS1</outRefId>
  <outRefId>_idS6</outRefId>
 </StartEvent>
 <ETLTask id="_idInputData" name="Input Data" type="Input Data">
  <File name="HR.csv" Type="csv"/>
  <inputs>
   <inputColumn name="EmployeeID"/>
   <inputColumn name=" ManagerID"/>
   <inputColumn name=" EmployeeJobCode "/>
    …
  </inputs>
  <inRefId>_idS1</inRefId>
  <outRefId>_idS2</outRefId>
 </ETLTask>
…
</ETLProcess>
```

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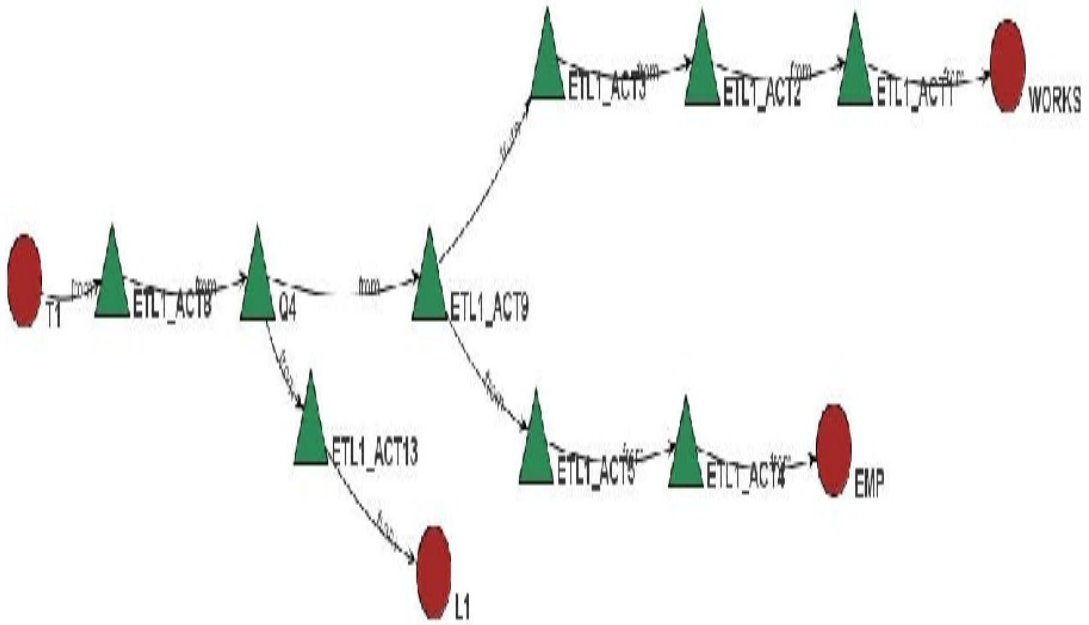
ETL Evolution (Current Approaches)

HECATAEUS Framework – based on rules/policies [4]

- Abstract ETL activities as queries and sequence of views
- Transforms SQL queries to graph
- User annotate graph with rules/policies (Propagate, Block, Prompt)
- System detects parts of the graph affected by a change in data source and highlights the way they respond to it



ETL Evolution (Current Approaches)

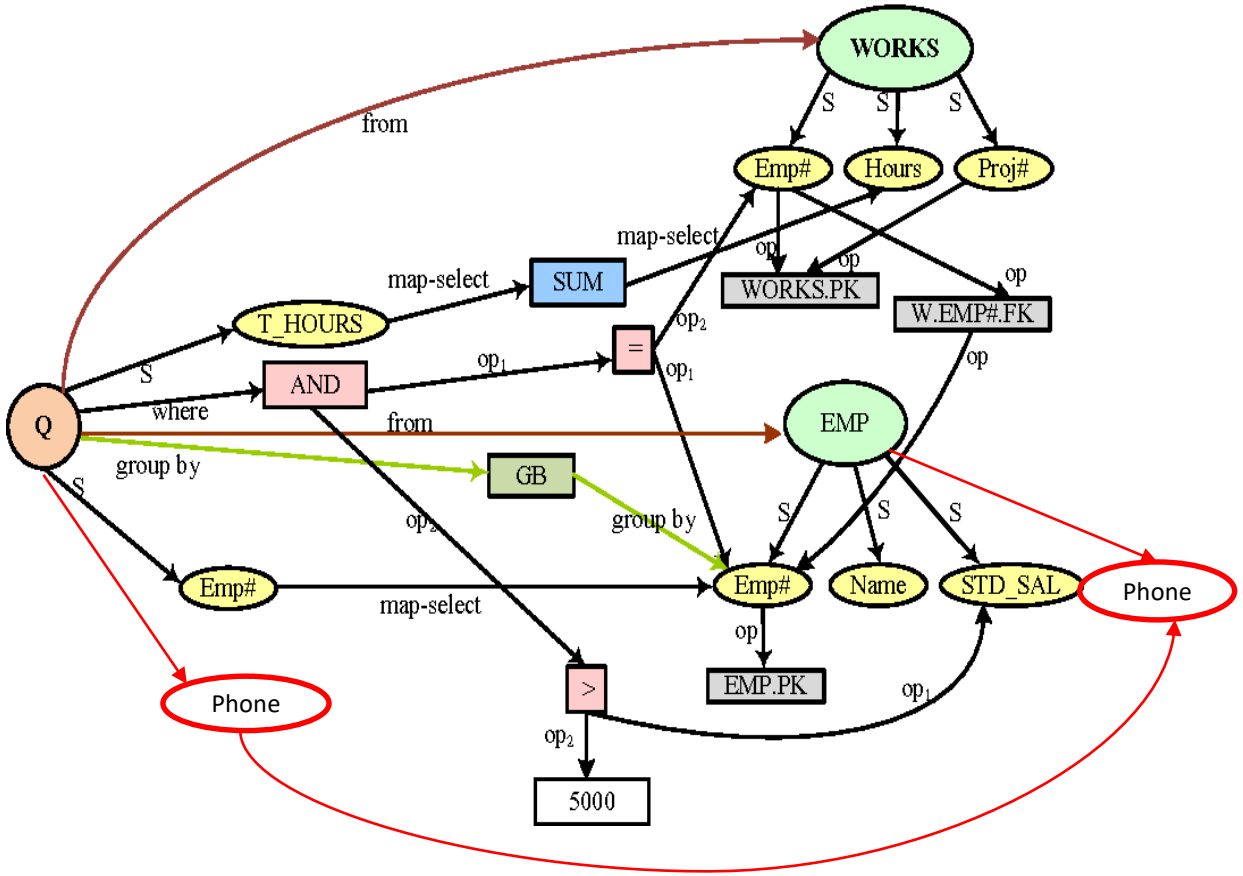
HECATAEUS

DS change = Add *Phone* to *EMP*

Policy = *Propagate*

Q: SELECT EMP.Emp# as Emp#, Sum(WORKS.Hours) as T_Hours FROM EMP, WORKS WHERE EMP.Emp# = WORKS.Emp# AND EMP.STD_SAL >5000 GROUP BY EMP.Emp#

Detailed graph representation of ETL1_ACT9



ETL Evolution (Current Approaches)

Concerns with Hecataeus

- Near manual – policies must be explicitly stated for each node
- User must determine policy in advance before evolution event occurs

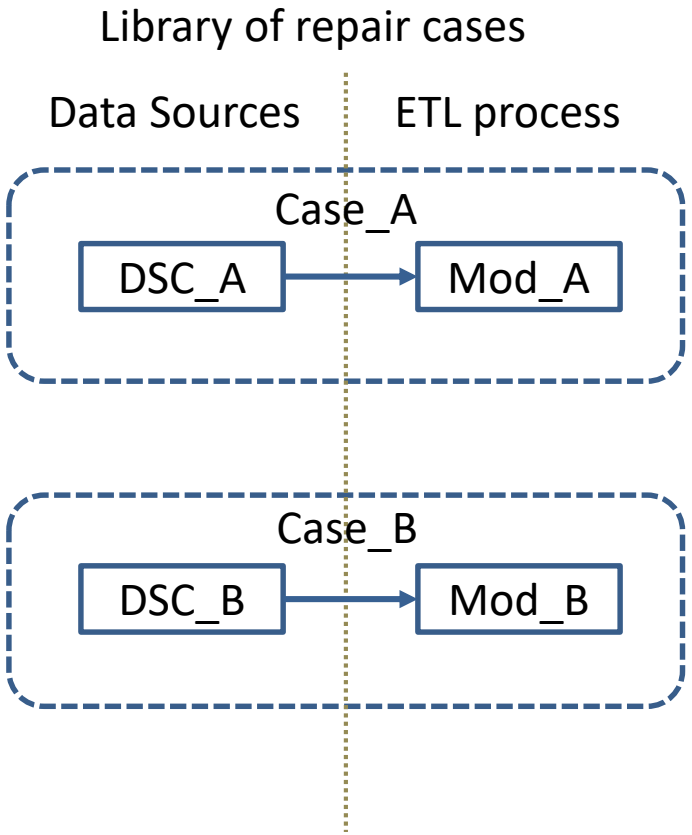
ETL Evolution (Current Approaches)

E-ETL (Evolving ETL) Framework – based on case-based reasoning [5]

- Applies case-based reasoning
- Keeps *library of repair cases (LRC)* as knowledge base

Concerns with E-ETL

- Developers cannot guarantee correctness
- It needs a case base in advance to work



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ETL Evolution (Our approach)

Subgoals:

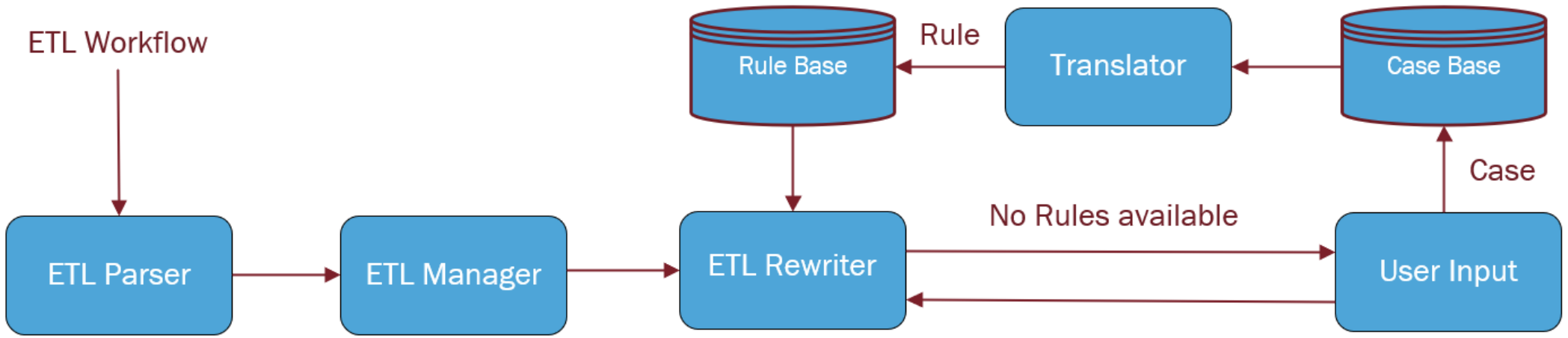
- Develop algorithms for (semi-)automatic repair of ETL workflows upon DS changes
  - Rules may be inferred from cases
  - Cases may be built from applying rules
  - Rule based + Case based (a quality measure for RB and CB)
- Develop an architecture for handling ETL evolution
- Implement a prototype
- Verify the applicability of the proposed solution with the TPC-DI benchmark [6]

ETL Evolution (Our approach)

Extended Evolving ETL (E3TL) framework

RBR + CBR

- ETL workflows are rewritten by applying rules
- Rules are inferred from cases (By applying algorithms)
- Cases are built from user input



ETL Evolution (Our approach)

Extended Evolving ETL (E3TL) framework – Learns rules from user input

Components:

ETL Parser: The ETL parser takes an entire ETL workflow in the form of RA or SQLs and parses the parts of each command of the workflow

ETL Manager: The ETL manager assesses the impact of the data source change on each command of the ETL workflow and takes these decisions by applying rules stored in a the rule base

ETL Rewriter: This component of the framework rewrites the commands in the ETL workflow by applying recommendations from the ETL manager

Rule Base: This contains distinct rules based on conditions

User Input: This part of the framework request the user's input if any of the following conditions is true:

- no rule is available in the rule base to deal with the problem
- several solutions are applicable to solve the problem

Case Base: This is a repository to store cases

Translator: This component applies algorithms to develop distinct rules from cases

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Conclusion

This project provides a means of managing ETL processes in two ways. First, their modelling and second, their reparation upon DS schema changes.

Currently, we have provided a modelling strategy of ETL processes with BPMN4ETL, an extended BPMN model for ETL at the conceptual level and with extended relational algebra (RA) extended with update operations at a logical level.

We propose the E3TL framework in which we will develop algorithms for (semi-) automatic repair of ETL workflows upon DS schema changes.

References

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