Information Integration project

Integrating heterogeneous data sources into a unified global schema

Goal of the project

Accomplishing a **domain-based integration of multiple and heterogenous data sources**, merging them into a single global view that can be queried by the users.

The global schema should be able to satisfy queries not trivially satisfiable by accessing directly the data sources.

GAV – Mappings (1)

In GAV approach, the (sound) mappings are assertions as such:

$\forall x.\ \phi S(x) \rightarrow g(x)$

Where:

- S is the source schema
- ϕS is a CQ over the source DB
- g is a predicate of arity n that indicates an element of G

GAV (Global As View): the global schema is a view of the set of sources

GAV – Retrieved global database (2)

Given I = <G, S, M> and source database C for S, we denote the retrieved global database as M(C), that is the database obtained by:

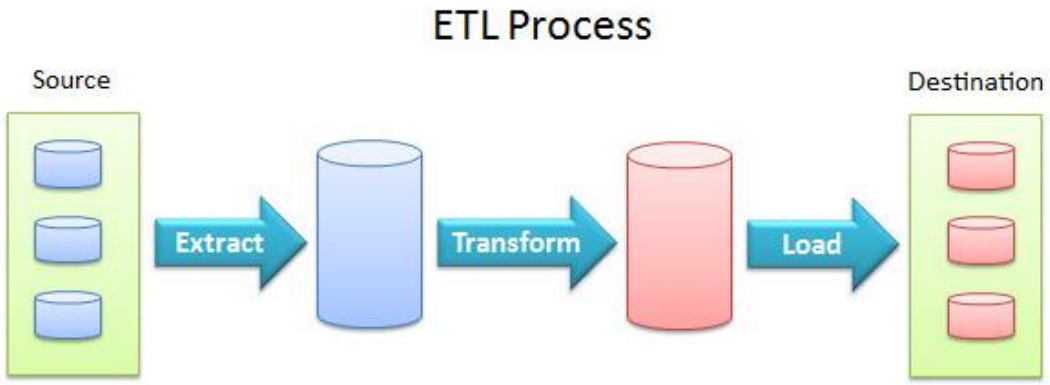
- Applying the CQs specified in the mappings
- Transferring the tuples from the sources to the global DB

Data integration using Pentaho (1)

The end result of the project is a **one-shot materialization** of the global schema, achieved by mappings in the form of Pentaho transformations.

Data integration using Pentaho (2)

Pentaho Kettle is a tool that allows loading input data in **heterogeneous formats and from different sources**, performing the transformations needed in order to map the information as requested.



Finally, the data is materialized in output as a SQL database in the example shown for this project.

Domain and data sources (1)

Critic reviews

Directors

Actors

Movies

Users Ratings

Production studios

Oscar awards

Domain and data sources (2)

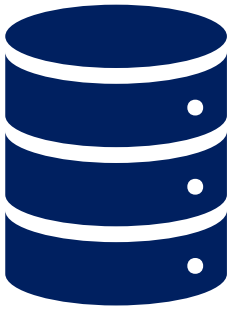
- 5 Data sources

- 11 Files (TSV and CSV)

- +45.000 Correctly reconciled movies across datasets

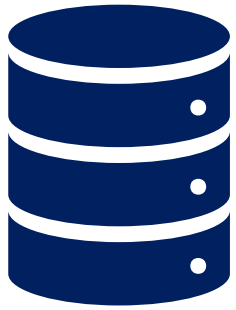
Domain and data sources (3)

IMDb



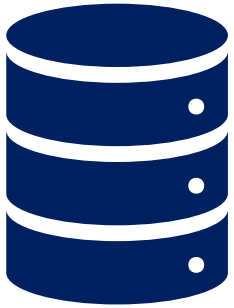
- title.principals.tsv
- title.basics.tsv
- name.basics.tsv

kaggle



- ratings.csv
- movies_metadata.csv
- links.csv

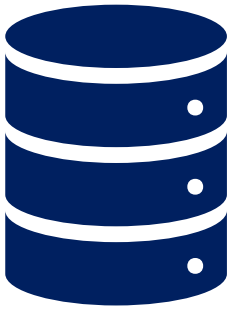
kaggle



- the_oscar_award.csv

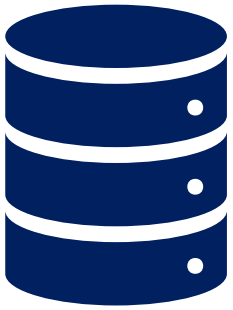
Domain and data sources (4)

kaggle



- studios.csv
- movies.csv

kaggle



- rotten_tomatoes_critic_reviews.csv
- rotten_tomatoes_movies.csv

Domain and data sources – Reconciliation issues (5)

- **Physical heterogeneity**

  Data stored in different formats: CSV and TSV
  Easily mitigated by Pentaho transformations that can handle multiple input formats

- **Conceptual heterogeneity**
  - Different datasets uniquely identify movies in diverse formats: IDs both in string and number data types
  - Some datasets refer to movies with their original title, some with their English title, some have both fields

Domain and data sources – Reconciliation issues (6)

- ## Contextual heterogeneity

  Datasets can refer to the same field using different representation: both IMDB and Movielens sources contain the IMDB ID, but the latter lacks a prefix in the string.

```python
import pandas as pd
import os

input_file = os.path.abspath("../datasets/links.csv")
output_file = os.path.abspath("../datasets/links_upd.csv")
column_name = "imdbId"

try:
    # Load the CSV file into a DataFrame
    df = pd.read_csv(input_file)

    # Ensure the specified column exists
    if column_name not in df.columns:
        raise ValueError(f"Column '{column_name}' not found in the CSV file.")

    # Update the column by prepending 'tt' to each value
    df[column_name] = 'tt' + df[column_name].astype(str)

    # Save the updated DataFrame to a new CSV file
    df.to_csv(output_file, index=False)
    print(f"Updated CSV file saved to {output_file}")

except Exception as e:
    print(f"An error occurred: {e}")
```

Python preprocessing required to solve the heterogeneity between sources

Source schema (1)

IMDBTitleBasics$_{/10}$ *(tconst, titleType, primaryTitle, originalTitle, isAdult, startYear, endYear, runtimeMinutes, genres)*

IMDBTitlePrincipals$_{/6}$ *(tconst, ordering, nconst, category, job, characters)*

IMDBNameBasics$_{/6}$ *(nconst, primaryName, birthYear, deathYear, primaryProfession, knownForTitles)*

MovielensRatings$_{/4}$ *(userId, movieId, rating, timestamp)*

MovielensMoviesMetadata$_{/24}$ *(adult, belongsToCollection, budget, genres, homepage, id, imdb_id, original_language, originalTitle, overview, popularity, poster_path, production_companies, production_countries, release_date, revenue, runtime, spoken_languages, status, tagline, title, video, vote_average, vote_count)*

MovielensLinks$_{/3}$ *(movieId, imdbId, tmdbId)*

Source schema (2)

TheOscarAward$_{/7}$ *(year_film, year_ceremony, ceremony, category, name, film, winner)*

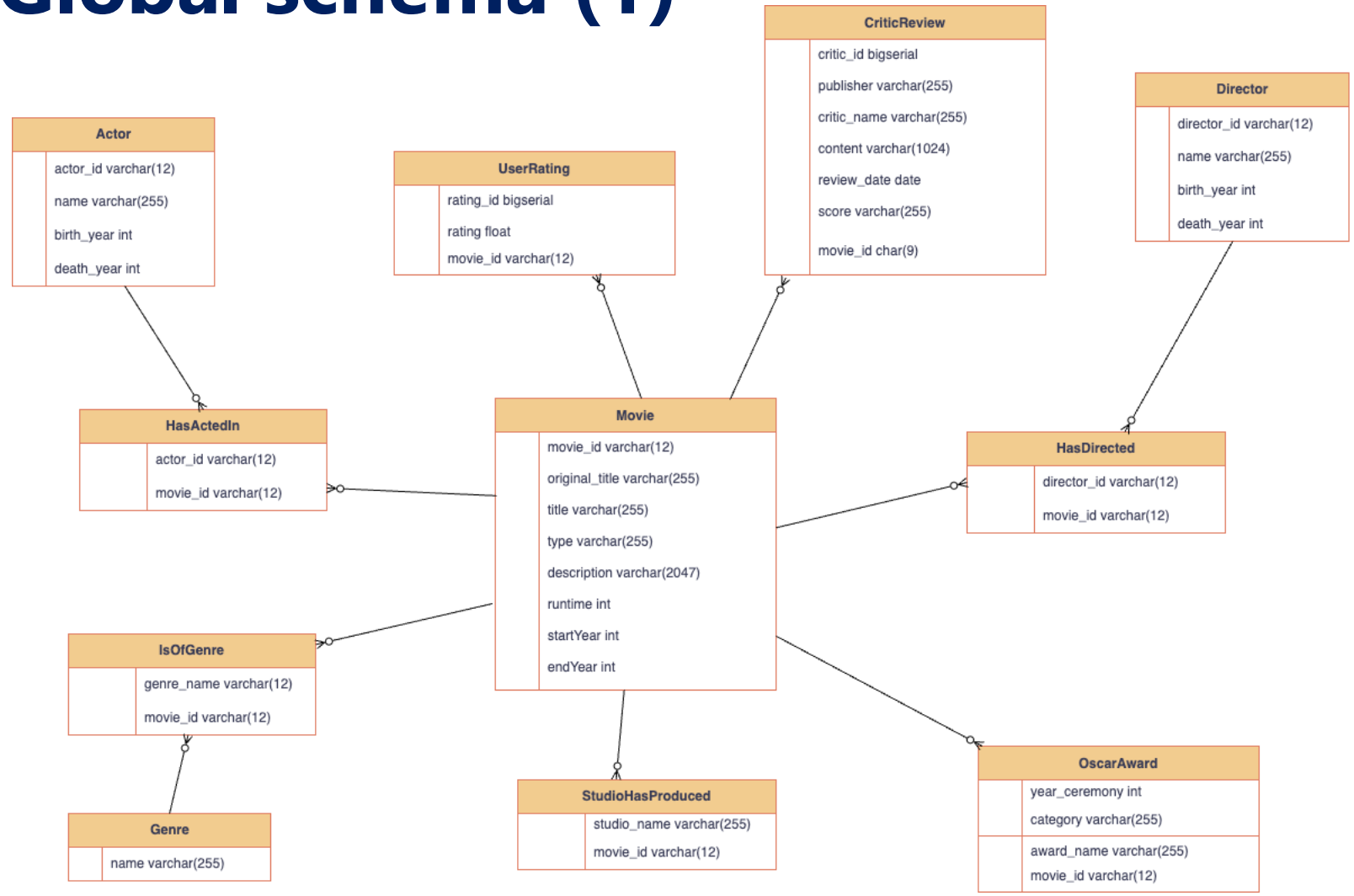
LetterboxStudios$_{/2}$ *(id, studio)*

LetterboxMovies$_{/7}$ *(id, name, date, tagline, description, minute, rating)*

RottenTomatoesCriticReviews$_{/8}$ *(rotten_tomatoes_link, critic_name, top_critic, publisher_name, review_type, review_score, review_date, review_content)*

RottenTomatoesMovies$_{/22}$ *(rotten_tomatoes_link, movie_title, movie_info, critics_consensus, content_rating, genres, directors, authors, actors, original_release_date, streaming_release_date, runtime, production_company, tomatometer_status, tomatometer_rating, tomatometer_count, audience_status, audience_rating, audience_count, tomatometer_top_critics_count, tomatometer_fresh_critics_count, tomatometer_rotten_critics_count)*

Global schema (1)



Global schema (2)

Movie$_{/8}$ *(movie_id, original_title, title, type, description, runtime, startYear, endYear)*

UserRating$_{/3}$ *(rating_id, rating, movie_id)*

CriticReview$_{/7}$ *(critic_id, publisher, critic_name, content, review_date, score, movie_id)*

Actor$_{/4}$ *(actor_id, name, birth_year, death_year)*

HasActedIn$_{/2}$ *(actor_id, movie_id)*

StudioHasProduced$_{/2}$ *(studio_name, movie_id)*

Global schema (3)

Director$_{/4}$ *(director_id, name, birth_year, death_year)*

HasDirected$_{/2}$ *(director_id, movie_id)*

Genre$_{/1}$ *(name)*

IsOfGenre$_{/2}$ *(genre_name, movie_id)*

OscarAward$_{/4}$ *(year_ceremony, category, award_name, movie_id)*

Conjunctive GAV FOL Mappings (1)

Movie:
∀ id, ot, ti, ty, dc, rt, sy, ey.(∃ ia, g, ad, btc, bg, hp, mid, ol, ott, pop, pp, pcp, pcn, rd, rev, rut, sl, st, tl, tit, va,vc.(**IMDBTitleBasics** (**id**, ty, ti, ot, ia, sy, ey, rt, g) ∧ **MovielensMovieMetadata**(ad, btc, bg, hp, mid, **id**, ol, ott, dc, pop, pp, pcp, pcn, rd, rev, rut, sl, st, tl, tit, va, vc))) → Movie(**id**, ot, ti, ty, dc, rt, sy, ey)

UserRating:
∀rid, r, mid.(∃ uid, mid2, ts, tid.(**MovielensRatings** (uid, mid2, r, ts) ∧ **MovielensLinks**(mid2, **mid**, tid))) → UserRating(rid, r, **mid**)

Genre:
∀g.(∃ id, ty, ti, ot, ia, sy, ey, rt.(**IMDBTitleBasics** (id, ty, ti, ot, ia, sy, ey, rt, g))) → Genre(g)

IsOfGenre:
∀g, id.(∃ id, ty, ti, ot, ia, sy, ey, rt.(**IMDBTitleBasics** (**id**, ty, ti, ot, ia, sy, ey, rt, g)))
→IsOfGenre(g, **id**)

Conjunctive GAV FOL Mappings (2)

Actor:
∀aid, n, by, dy.(∃ pp, kft.(**IMDBNameBasics**(aid, n, by, dy, pp, kft)))
→ Actor(aid, n, by, dy)

HasActedIn:
∀aid, mid.(∃ o, ca, j, ch.(**IMDBTitlePrincipals**(mid, o, aid, ca, j, ch) ∧ ca = '$actor$'))
→ HasActedIn(aid, mid)

Director:
∀did, n, by, dy.(∃ pp, kft.(**IMDBNameBasics**(did, n, by, dy, pp, kft)))
→ Actor(did, n, by, dy)

HasDirected:
∀did, mid.(∃ o, ca, j, ch.(**IMDBTitlePrincipals**(did, o, aid, ca, j, ch) ∧ ca = '$director$'))
→ HasDirected(did, mid)

StudioHasProduced:
∀sn, mid.(∃ mid2, n, d, tl, dc, m , ty, ot, ia, ey, rt, g, r.(**LetterboxStudios**(mid2, sn) ∧
LetterboxMovies(mid2, n, d, tl, dc, m, r) ∧
IMDBTitleBasics (**mid**, ty, n, ot, ia, d, ey, rt, g))) → StudioHasProduced(sn, **mid**)

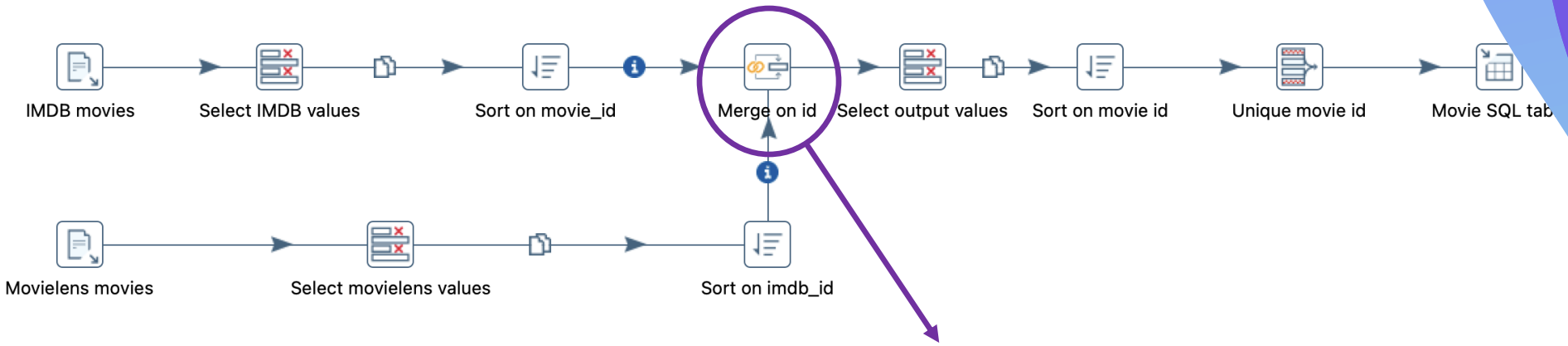
Conjunctive GAV FOL Mappings (3)

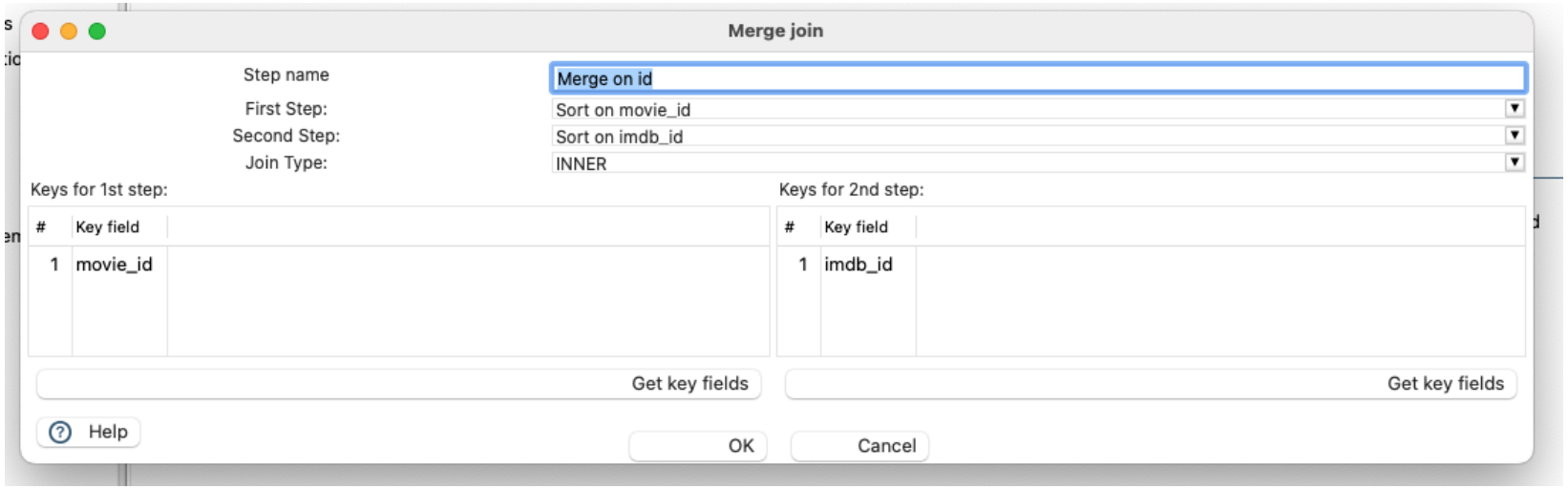
CriticReview:
∀cid, p, cn, ct, rd, sc, mid.
(∃ rtl, tc, rt, mt, mi, cc, cr, g, d, a, ord, srd, r, pc, ts, tr, tc, as, ar, ac, ttcc, tfcc, trcc, ty, ot, ia, ey, rt2, g2. (RottenTomatoesCriticReviews (rtl, cn, tc, p, rt, sc, rd, ct) ∧ RottenTomatoesMovies(rtl, mt, mi, cc, cr, g, d, a, ord, srd, r, pc, ts, tr, tc, as, ar, ac, ttcc, tfcc, trcc) ∧ IMDBTitleBasics (mid, ty, mt, ot, ia, d, ey, rt2, g2))) → CriticReview(cid, p, cn, ct, rd, sc, mid)

OscarAward:
∀ yc, ca, an, mid.
(∃ yf, ce, n, f, w, ty, ot, ia, ey, rt, g. TheOscarAward(yf, yc, ce, ca, n, f, w) ∧ IMDBTitleBasics (mid, ty, f, ot, ia, yf, ey, rt, g) ∧ w='true') → OscarAward(yc, ca, an, mid)

Pentaho implementation (1)

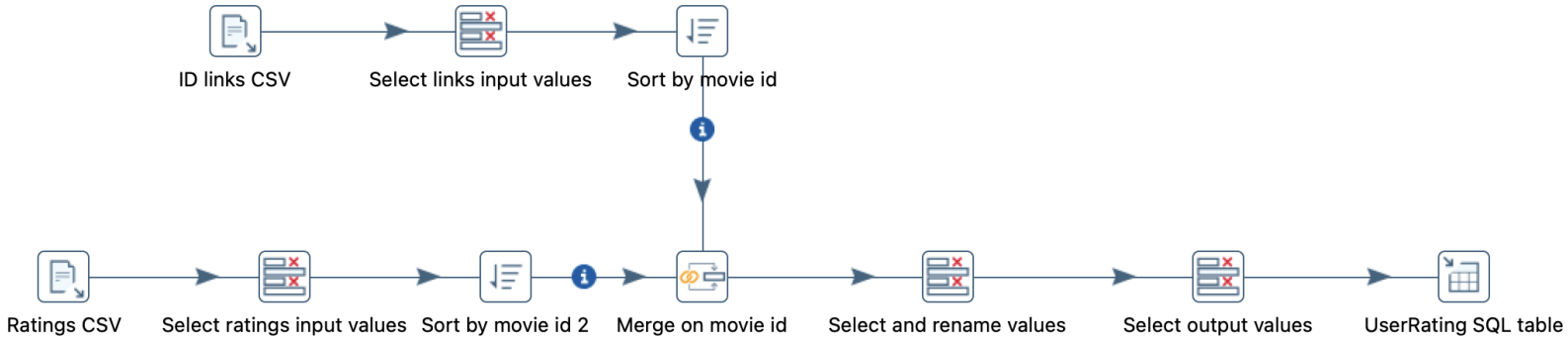
Movie transformation



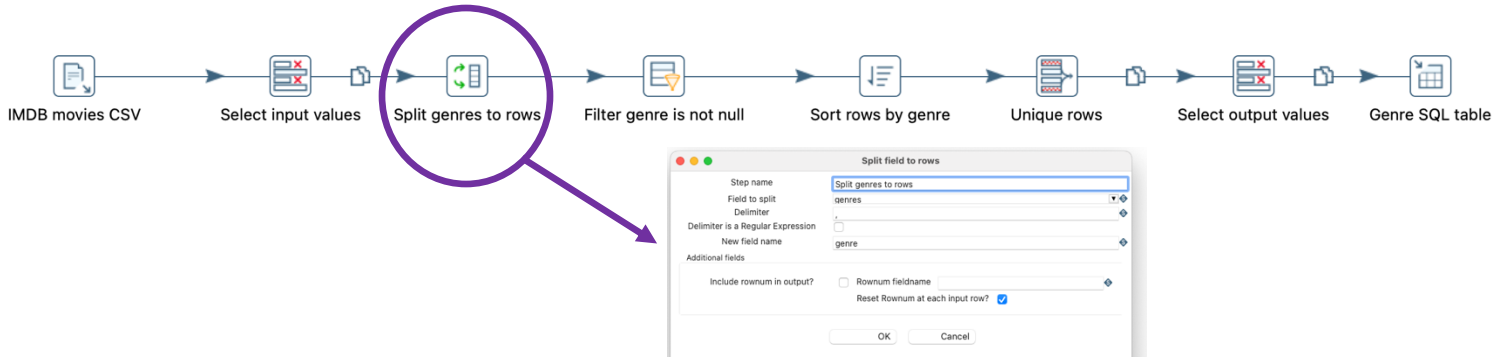


Pentaho implementation (2)

UserRating transformation



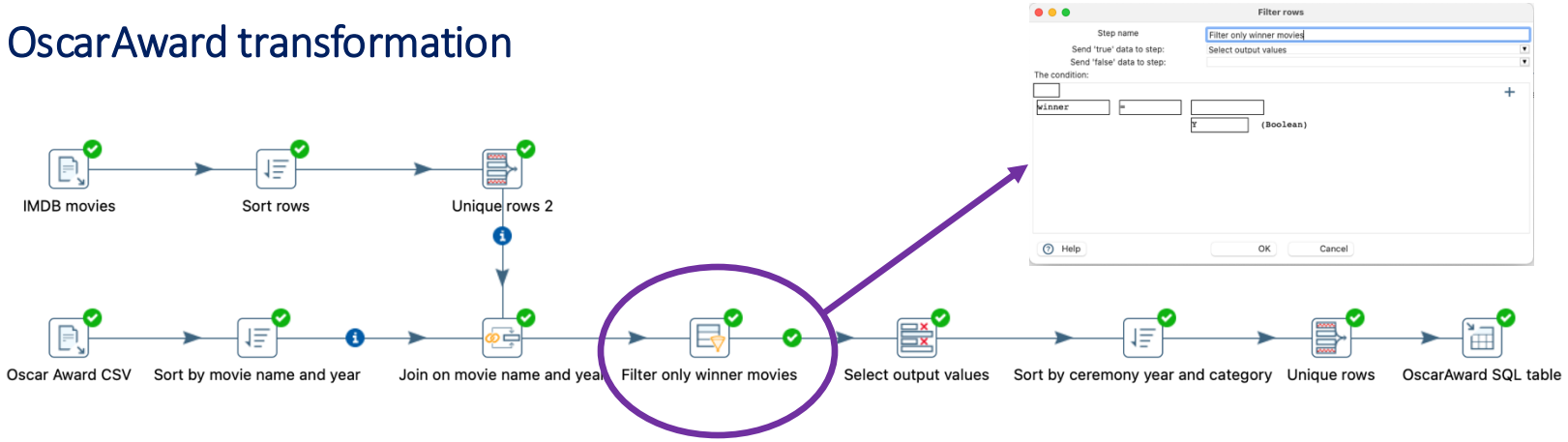
Genre transformation



Pentaho implementation (3)

IsOfGenre transformation

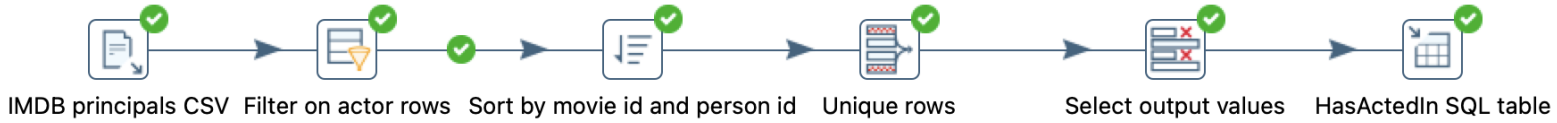
OscarAward transformation



Pentaho implementation (4)

Actor transformation

HasActedIn transformation



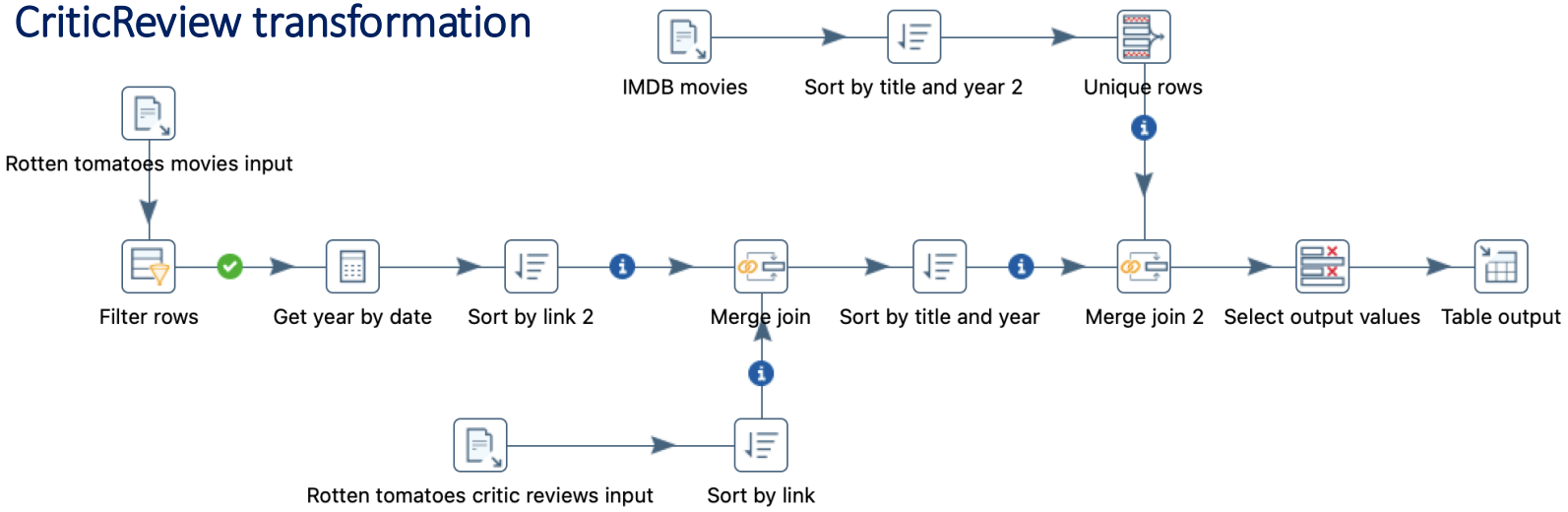
Pentaho implementation (5)

Director transformation

HasDirected transformation

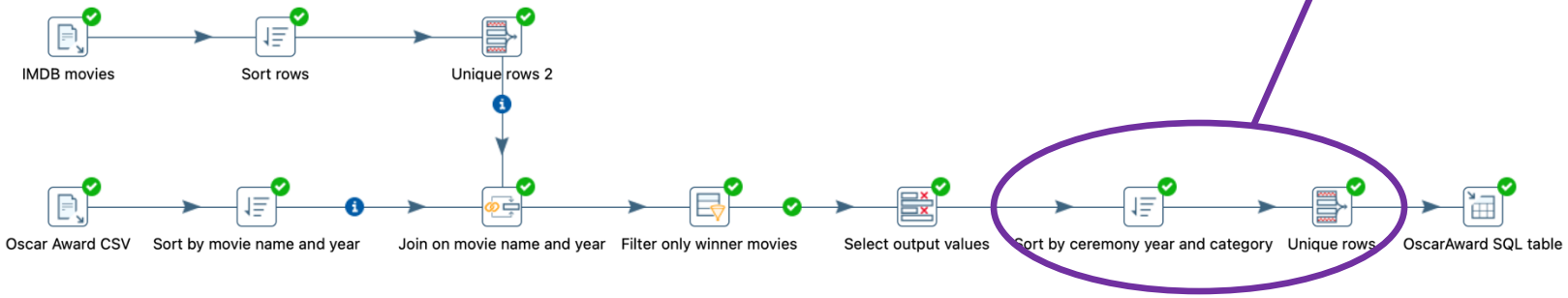
Pentaho implementation (6)

CriticReview transformation



OscarAward transformation

Strange case of duplicate Oscar Award (Aladdin 1993)



Some statistics…

- In the RGBD (Retrieved Global Database)
  - **>11.000.000** movies
  - **>26.000.000** reconciled user ratings
  - **>20.000.000** actor appearances

- **17 minutes each** for CriticRating, OscarAward, StudioHasProduced transformations (ran on M1 Pro)

- **7,09 GBs** of source data

Query answering

Given the source database C, now that we have obtained the **RGBD (Retrieved Global Database)** M(C) by performing a one-shot materialization, we can query it

We have proved that, given GAV mappings with sound sources and conjunctive queries, we can compute **certain answers** in polynomial time complexity

Query 1

Name of actors born after 1960 participating in a "Best Picture" Oscar-winning movie, criticized by the Independent (UK) publisher

```
select distinct a."name"
from actor a, hasactedin h, movie m, oscaraward o, criticreview c
where a.actor_id = h.actor_id
      and h.movie_id = m.movie_id
      and m.movie_id = o.movie_id
      and m.movie_id = c.movie_id
      and birth_year > 1960
      and o.category = 'BEST PICTURE'
      and c.publisher = 'Independent (UK)'
```

	A-Z name
1	Azharuddin Mohammed Ismail
2	Danny Dorland
3	Dev Patel
4	Dominic West
5	Irrfan Khan
6	Javier Bardem
7	John C. Reilly
8	Joseph Fiennes
9	Josh Brolin
10	Mark Ivanir
11	Martin Clunes

$q = \{(name) \mid$
$\exists$ aid, mid, name, by, dy, ot, ti, ty, dc, r, sy, ey, yc, cat, aw, cid, pub, cn, co, rd,sc.
Actor(aid, name, by, dy) $\wedge$ HasActedIn(aid, mid)
$\wedge$ Movie(mid, ot, ti, ty, dc, r, sy, ey) $\wedge$ OscarAward(yc, 'BEST PICTURE', aw, mid)
$\wedge$ CriticReview(cid, 'Independent (UK)', cn, co, rd, sc, mid) $\wedge$ by > 1960$\}$

Query 2

Name of movies of genre Drama produced by "Paramount Pictures" where Cillian Murphy acted

```
select m.title
from genre g, isofgenre i, movie m, hasactedin h, studiohasproduced s, actor a
where g."name" = i.genre_name
     and i.movie_id = m.movie_id
     and m.movie_id = s.movie_id
     and i.movie_id = h.movie_id
     and h.actor_id = a.actor_id
     and s.studio_name = 'Paramount'
     and a."name" = 'Cillian Murphy'
     and g."name" = 'Drama'
```

	A-Z title
1	A Quiet Place Part II
2	On the Edge

$$q = \{(title) \mid \exists\ aid, mid, by, dy, ot, ty, dc, r, sy, ey, . \\ Actor(aid, \text{‘Cillian Murphy’}, by, dy) \wedge HasActedIn(aid, mid) \\ \wedge Movie(mid, ot, title, ty, dc, r, sy, ey) \wedge IsOfGenre(\text{‘Drama’}, mid) \wedge \\ StudioHasProduced(\text{‘Paramount’}, \text{‘Cillian Murphy’})\}$$

Query 3

Name of critics that have criticized a movie directed by Cristopher Nolan where Al Pacino acted

query elapsed time to join actors, movies and directors: ~5 minutes

```
select c.critic_name
from actor a, hasactedin h, movie m, hasdirected h2, criticreview c, director d
where a.actor_id = h.actor_id
      and h.movie_id = m.movie_id
      and m.movie_id = h2.movie_id
      and h2.director_id = d.director_id
      and m.movie_id = c.movie_id
      and d.name = 'Christopher Nolan'
      and a."name" = 'Al Pacino'
```

	A-Z critic_name
1	Rob Blackwelder
2	Harvey S. Karten
3	Richard Roeper
4	Robin Clifford
5	Jeanne Aufmuth
6	Ed Gonzalez
7	Kevin N. Laforest
8	Frank Swietek
9	Andy Weil
10	Steve Rhodes
11	Kirk Honeycutt

$$
\begin{aligned}
&q = \{(name) \mid \\
&\exists\ aid, mid, by, dy, ot, ti, ty, dc, r, sy, ey, did, by2, dy2, cid, pub, co, rd, sc. \\
&Actor(aid, \text{‘Al Pacino’}, by, dy) \wedge HasActedIn(aid, mid) \\
&\wedge Movie(mid, ot, ti, ty, dc, r, sy, ey) \wedge HasDirected(did, mid) \\
&\wedge Director(did, \text{‘Cristopher Nolan’}, by2, dy2) \\
&\wedge CriticReview(cid, pub, name, co, rd, sc, mid)\}
\end{aligned}
$$

Query 4

Name of directors and movie titles of oscar-winning movies in the DIRECTING category, produced by Warner Bros, with at least one user rating less than 0.5

```
select distinct d."name", m.title
from movie m, oscaraward o, studiohasproduced s, userrating u, hasdirected h, director d
where m.movie_id = o.movie_id
     and m.movie_id = u.movie_id
     and s.movie_id = m.movie_id
     and h.movie_id = m.movie_id
     and h.director_id = d.director_id
     and u.rating <= 0.5
     and s.studio_name = 'Warner Bros. Pictures'
     and o.category = 'DIRECTING'
```

	A-Z name	A-Z title
1	Alfonso Cuarón	Gravity

q = {(name, title) |
∃ did, by, dy, mid, ot, ty, dc, r, sy, ey, yc, aw, rid, rating.
Director(did, name, by, dy) ∧ HasDirected(did, mid)
∧ Movie(mid, ot, title, ty, dc, r, sy, ey)
∧ StudioHasProduced('Warner Bros. Pictures', mid)
∧ OscarAward(yc, 'DIRECTING', aw, mid)
∧ UserRating(rid, rating, mid) ∧ rating <= 0,5}

Query 5

Title of horror movies that last less than 100 minutes, and name of actors participating, born after the year 2000, with a critic review on rotten tomato

```
select distinct m.title, a."name"
from movie m, genre g, isofgenre i, criticreview c, hasactedin h, actor a
where m.movie_id = i.movie_id
      and g."name" = i.genre_name
      and h.movie_id = m.movie_id
      and h.actor_id = a.actor_id
      and c.movie_id = m.movie_id
      and a.birth_year >= 2000
      and g."name" = 'Horror'
      and m.runtime < 100
```

	title	name
1	14 Cameras	Gavin White
2	211	Michael Rainey Jr.
3	Annabelle	Gabriel Bateman
4	Artik	Gavin White
5	Brightburn	Jackson A. Dunn
6	Children of the Corn	Preston Bailey
7	Eli	Austin Foxx
8	Eli	Charlie Shotwell
9	Haunter	Peter DaCunha
10	Hellions	Peter DaCunha
11	Incarnate	David Mazouz
12	Little Evil	Owen Atlas

$$
\begin{aligned}
&q = \{(title, name) \mid \\
&\exists\ aid, by, dy, mid, ot, ty, dc, rt, sy, ey, cid, pub, cname, co, rd, sc. \\
&Actor(aid, name, by, dy) \wedge HasActedIn(aid, mid) \\
&\wedge Movie(mid, ot, title, ty, dc, rt, sy, ey) \\
&\wedge IsOfGenre(\text{‘Horror’}, mid) \\
&\wedge CriticReview(cid, pub, cname, co, rd, sc, mid) \\
&\wedge by >= 2000 \wedge rt < 100\}
\end{aligned}
$$

...Thanks!

References

- Theoretical notions: LSDM course taught by prof. Antonella Poggi
- Github: Github repository
- Datasets: see README file in repository
- Guide link to install Pentaho Kettle on Apple Silicon