Karlsruhe Institute of Technology

Definition and Materialisation of the Global Cube from Multidimensional Datasets on the Web

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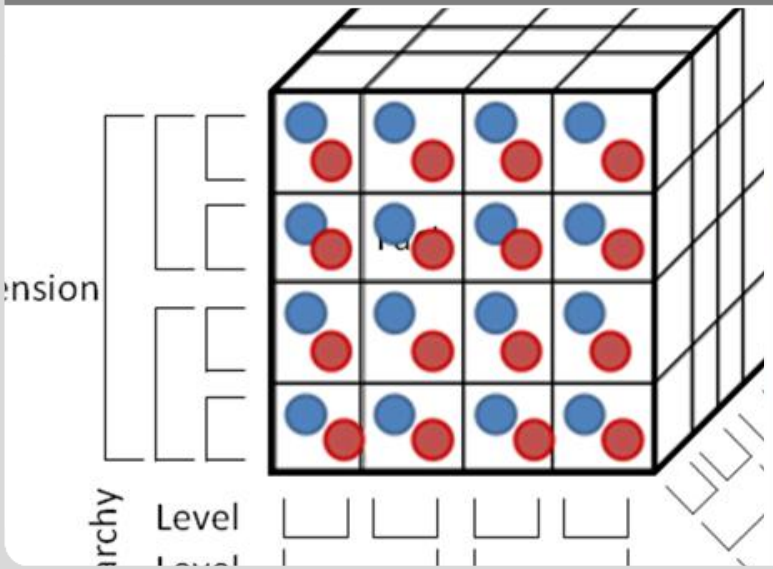
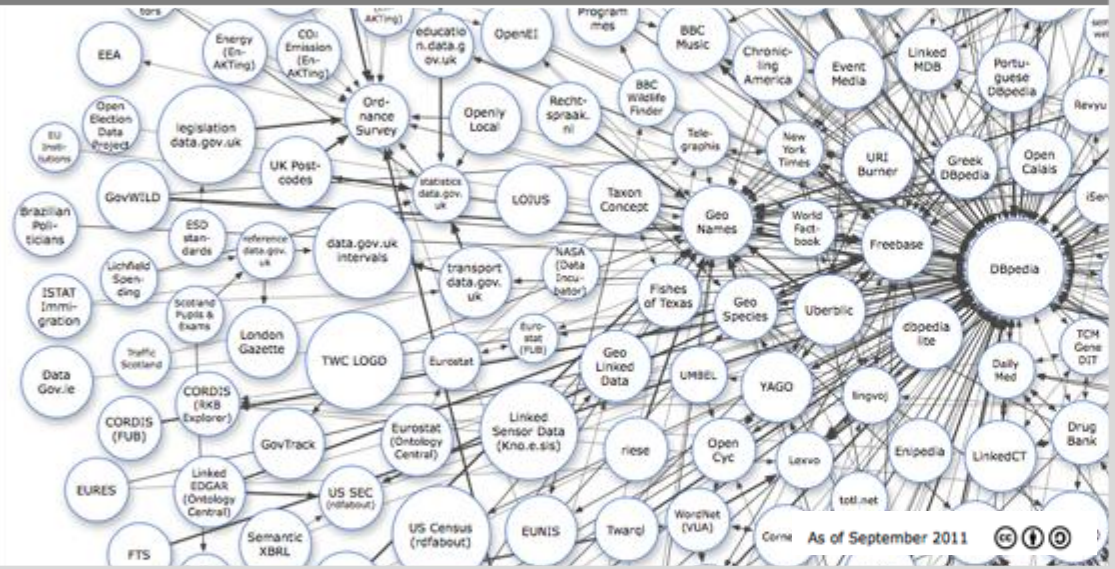
MUGS

Institute of Applied Informatics and Formal Description Methods (AIFB)

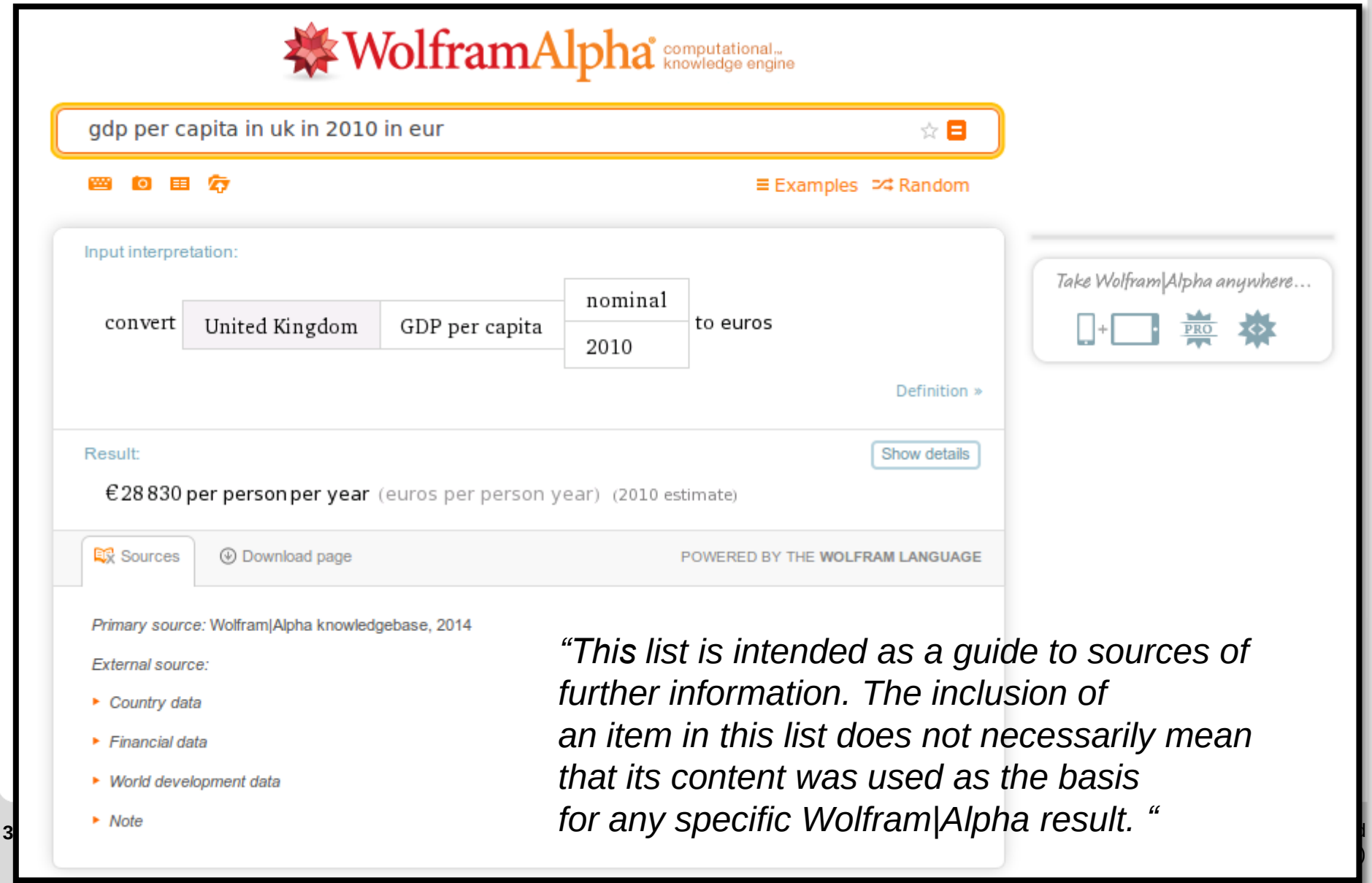




Motivation


WolframAlpha computational... knowledge engine
gdp per capita in uk in 2010 in eur
Examples
Random
Input interpretation:
convert
United Kingdom
GDP per capita
nominal
2010
to euros
Definition »
Result:
Show details
€28 830 per person per year (euros per person year) (2010 estimate)
Sources
Download page
POWERED BY THE WOLFRAM LANGUAGE
Take Wolfram|Alpha anywhere...
PRO

Motivation



"This list is intended as a guide to sources of further information. The inclusion of an item in this list does not necessarily mean that its content was used as the basis for any specific Wolfram|Alpha result. "

Query in Terms of the Global Cube

```
datacube(globalcube).
dimension(globalcube, geo).
dimension(globalcube, unit).
dimension(globalcube, date).
dimension(globalcube, indicna).
dimension(globalcube, sex). ...
measure(globalcube, obsvalue).
globalcube(Geo, Unit, Date, Indicna, ...,
  Obsvalue).

?- globalcube(uk, eur_hab, 2010, ngdph, all,
  ..., Obsvalue).
```

Outline

- Global Cube
- Heterogeneity Problems
- Analysis of Size of Global Cube

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- **Global Cube**
- Heterogeneity Problems
- Analysis of Size of Global Cube

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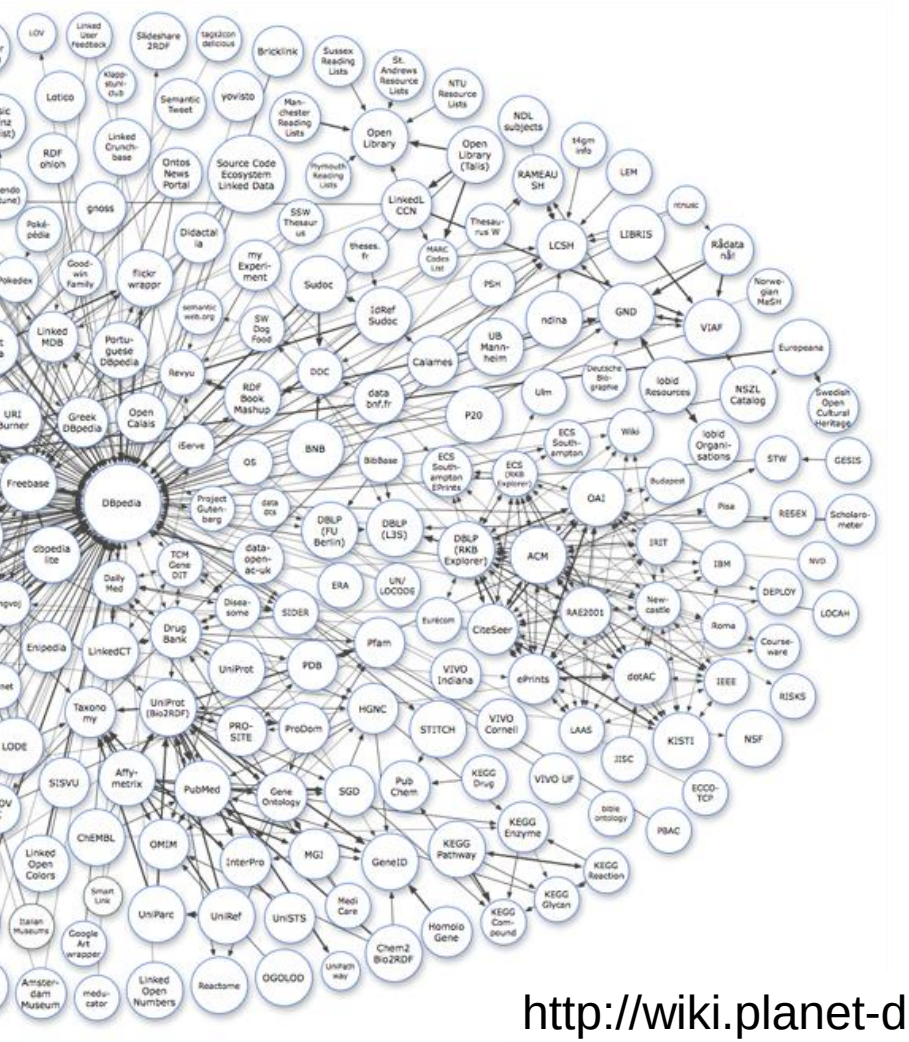
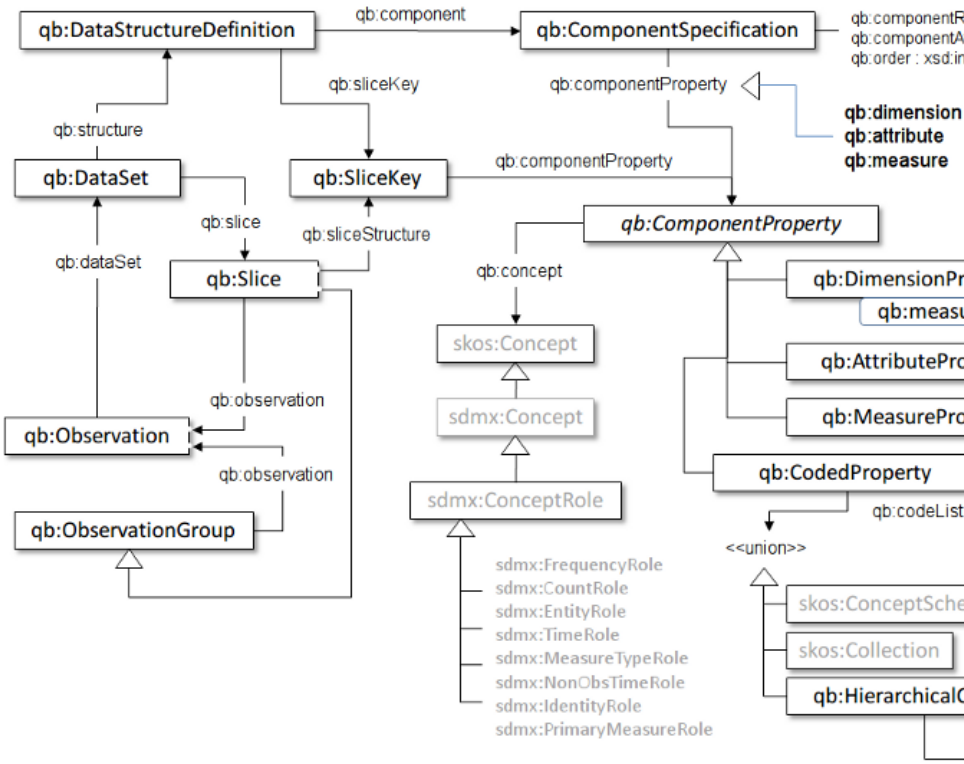
Assumption: Linked Data and The RDF Data Cube Vocabulary





http://wiki.planet-data.eu/web/Datasets

Multidimensional Dataset

```
datacube(eurostat:id/nama_gdp_c#ds).
dimension(eurostat:id/nama_gdp_c#ds, estatwrap:geo).
dimension(eurostat:id/nama_gdp_c#ds, estatwrap:unit).
dimension(eurostat:id/nama_gdp_c#ds, dcterms:date).
dimension(eurostat:id/nama_gdp_c#ds, estatwrap:indic_na).
measure(eurostat:id/nama_gdp_c#ds, sdmx-measure:obsValue).

eurostat:id/nama_gdp_c#ds(Estatwrap:geo, Estatwrap:unit,
  Dcterms:date, Estatwrap:indic_na, Sdmx-measure:obsValue).

eurostat:id/nama_gdp_c#ds(uk, mioeur, 2010, ngdp, 1731809).
```

Linked Data URIs serving RDF, e.g.,
http://estatwrap.ontologycentral.com/id/nama_gdp_c#ds

Multidimensional Dataset (readable)

```
datacube(gdpcomponents).
dimension(gdpcomponents, geo).
dimension(gdpcomponents, unit).
dimension(gdpcomponents, date).
dimension(gdpcomponents, indicna).
measure(gdpcomponents, obsvalue).

gdpcomponents(Geo, Unit, Date, Indicna, Obsvalue).


gdpcomponents(uk, mioeur, 2010, ngdp, 1731809).
```

Global Cube Definition: Unempl. Fear Example (UNEMPLOY)

```
datacube(gdpgrowth).
datacube(unemployfear).

dimension(gdpgrowth, geo).
dimension(gdpgrwoth, unit).
dimension(gdpgrwoth, date).

dimension(unemployfear, geo).
dimension(unemployfear, date).
dimension(unemployfear, variable).
```

Global Cube Definition: UNEMPLOY (2)

```
dimension(globalcube, X) :-
  dimension(Y, X).


globalcube(Geo, Unit, Date, Variable,
  Obsvalue).
globalcube(Geo, Unit, Date, all,
  ObsValue) :- gdpgrowth(Geo, Unit,
  Date, Obsvalue).
globalcube(Geo, all, Date, Variable,
  ObsValue) :- unemployfear(Geo, Date,
  Variable, Obsvalue).
```

Requirements

- Correct GDP per Capita – confirmed by as many data sources as possible.

- In case there are differences between data sources – we want to know about it.

Outline

- Global Cube
- **Heterogeneity Problems**
- Analysis of Size of Global Cube

Heterogeneity Problems

- different dimensions, e.g., sex, age...
- different names for dimensions, e.g., “geo” – “loc”
- ... or for values, e.g., “UK“ vs. “United Kingdom“
- units of measurements, e.g., “mio eur” vs “eur“
- compound indicators, e.g., GDP per Capita
- ...

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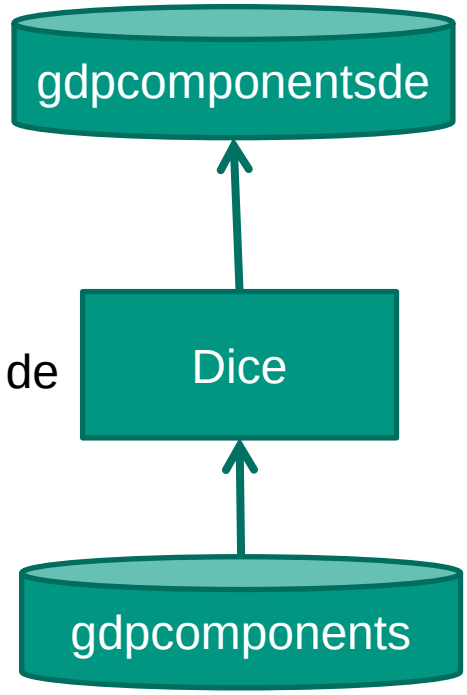
OLAP Operations (Projection, Dice, Slice, Roll-Up, Drill-Across)

```
Dice(gdpcomponents, {(Geo = de)})
```



Usually represented in SQL over Star Schema

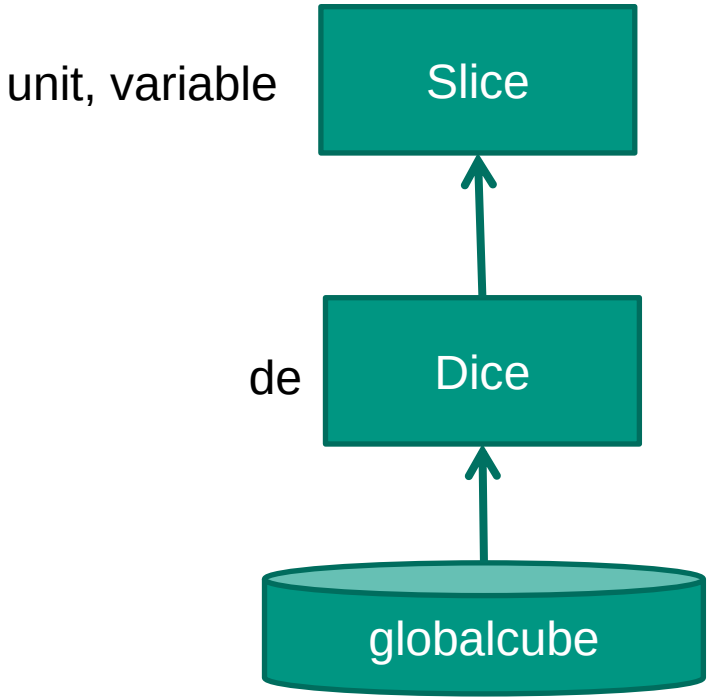
Also possible in Datalog:

```
gdpcomponentsde(Geo, Unit, Date,
  Indicna, Obsvalue) :-
  gdpcomponents(de, Unit, Date,
  Indicna, Obsvalue).
```

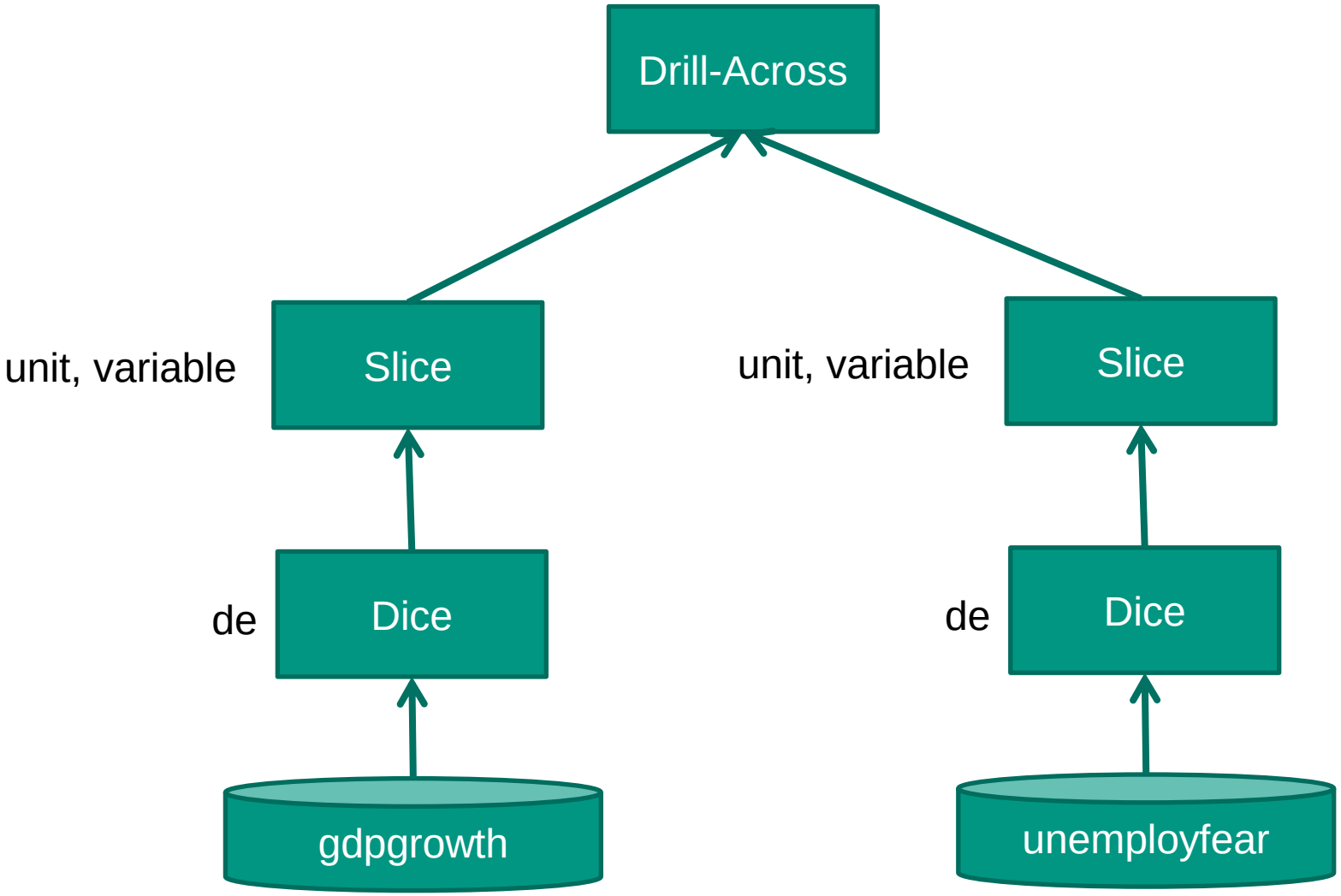
Slice / Roll-Up: Require aggregation (Abhijeet)

Query over the Global Cube (UNEMPLOY)

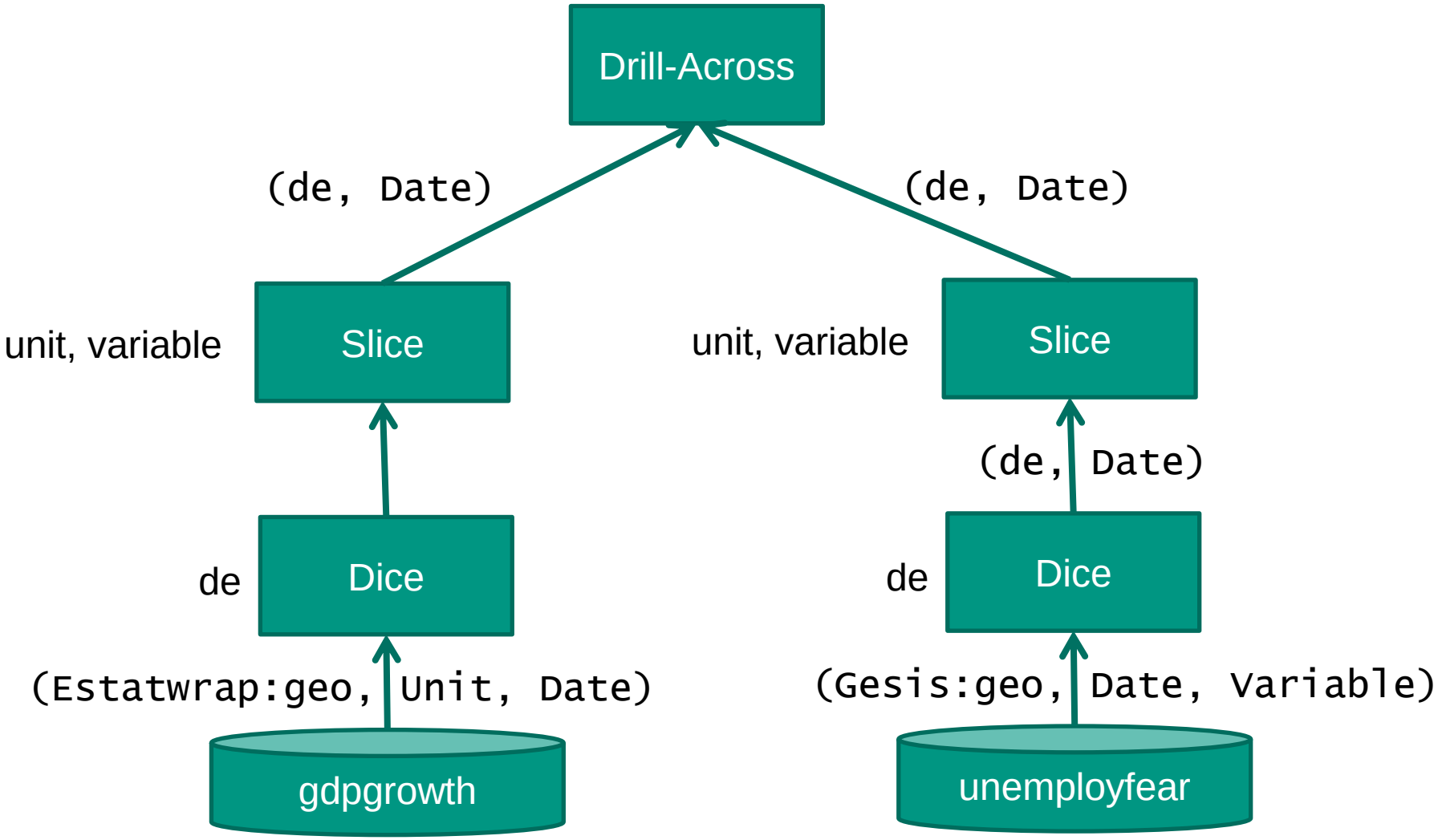
```
Slice(Dice(Projection (globalcube, { obsvalue avg }),
   {Geo = de}), {unit, variable})
```



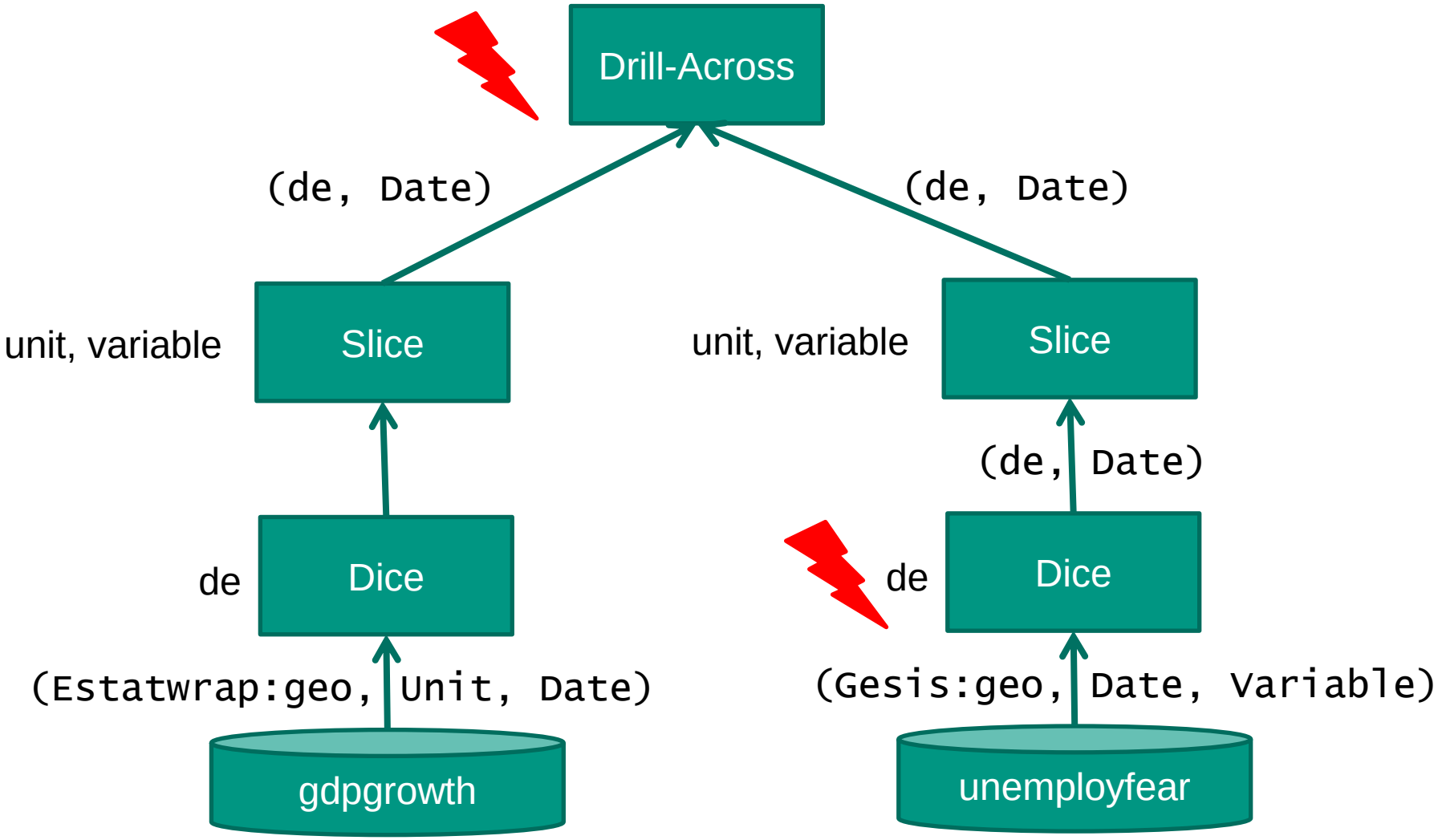
Translated Query over the Global Cube (UNEMPLOY)



Different Names Problem (UNEMPLOY)



Different Names Problem (UNEMPLOY)



Different Names Problem – Solution

OWL equivalence statements in RDF

```
owl:sameAs(estatwrap:geo, gesis:geo).
eurostat-geo:DE owl:sameAs gesis-
  geo:00 .
```

Duplication interpretation of OWL semantics

```
gdpgrowth(Estatwrap:geo, Gesis:geo,
  Unit, Date, Obsvalue)
unemployfear(Estatwrap:geo, Gesis:geo,
  Date, Variable, Obsvalue)
```

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- units of measurements, e.g., “mio eur” vs “eur“
- compound indicators, e.g., GDP per Capita
- ...

Units and Compounds Problem

```
gdppercapita(uk, eur_hab, 2010, ngdph,
  27800).
gdpcomponents(uk, mioeur, 2010, ngdp,
  1731809).
population(uk, hab, 2010, t, total,
  62510197).


? :- globalcube(uk, eur_hab, 2010,
  ngdph, all, all, Obsvalue).
```

Units and Compounds Problem – Solution

Conversion and Merging Correspondences (declarative)

```
MIO2EUR =
({(unit, :MIO_EUR)}, {(unit, :EUR)}, f (x) = 1, 000, 000 · x)

COMP_GDP_CAP = (
{(indic_na, :NGDP), (unit, :EUR)}, {(sex, :T), (age, :TOTAL)},
{(indic na, :NGDPH), (unit, :EUR HAB)},
f (x 1 , x 2 ) = x 1 /x 2 )
```

Convert-Cube and Merge-Cubes operations

```
datacube(MIO2EUR(X)) :- datacube(X).

datacube(COMP_GDP_CAP(X,Y)) :- datacube(X), datacube(Y).
```

Can be executed using Datalog/Prolog

Architecture of Integration System

- GDP Per Capita (GDP_CAP)

  Looked-up: 27,800

  vs.

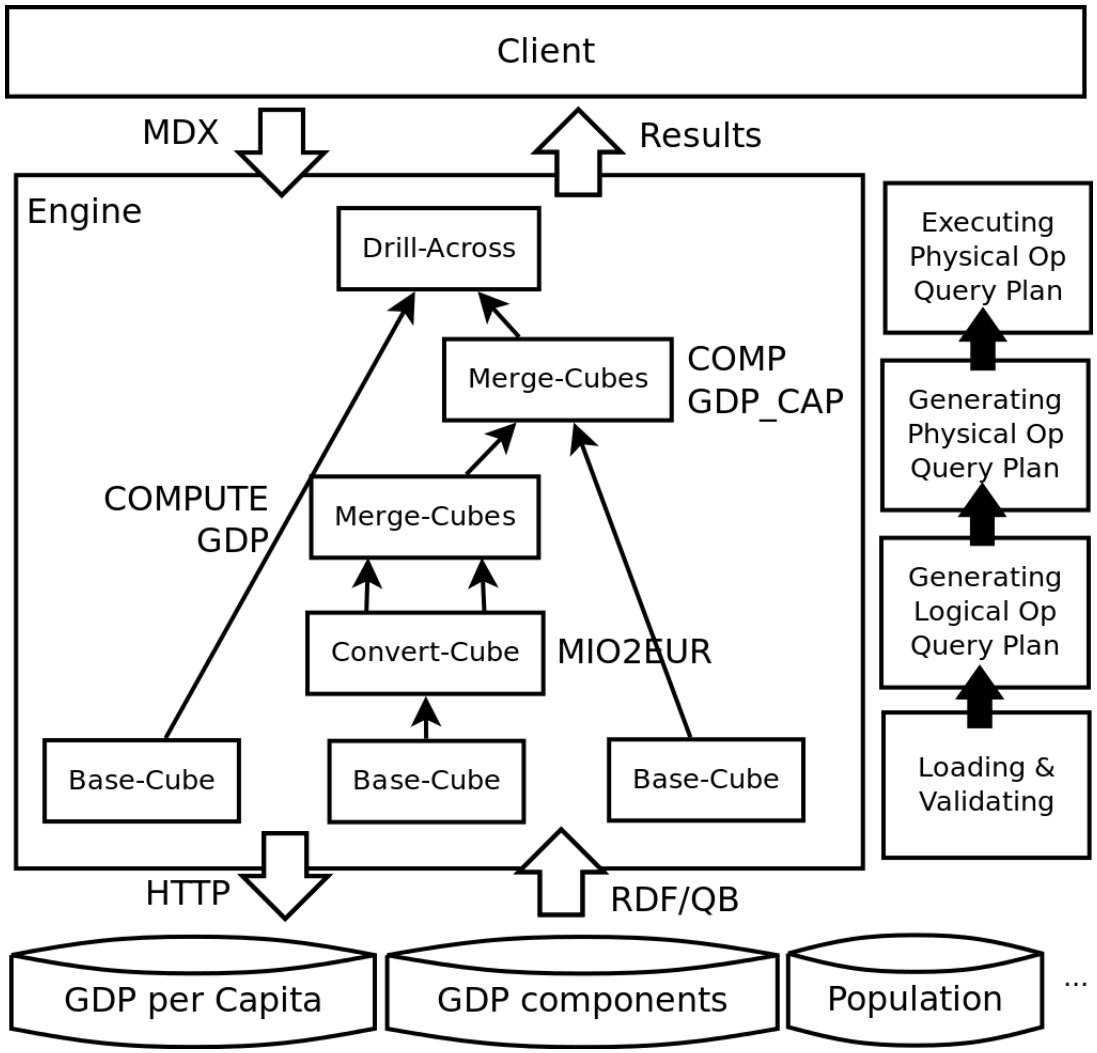
  Computed: 27,704

- Execution

  Top-Down

  vs.

  Bottom-Up



Outline

- Global Cube
- Heterogeneity Problems
- **Analysis of Size of Global Cube**

Analysis of Size of Global Cube

Depending on number of derived data cubes from conversion and merging operations:

1. No restrictions
2. No cycles
3. Matching of dimension-member combinations

How to restrict the possible number of conversion and merging operations?

1) No restrictions

```
datacube(gdppercapita).
datacube(mio2eur(X)) :- datacube(X).
```

Unlimited

How to restrict the possible number of conversion and merging operations? (2)

2) No repeated applications / cycles

```
datacube(mio2eur(X)) :- datacube(X), \+
  derivedby(X, mio2eur).
derivedby(mio2eur(X), mio2eur) :-
  datacube(X), \+ derivedby(X, mio2eur).
```

noderiveds(ds, mc) a lot, XSB Prolog would not be able to compute them in GDP per Capita scenario (1x Convert-Cube, 2x Merge-Cubes)

How to restrict the possible number of conversion and merging operations? (3)

3) Considering matching dimension-member combinations

```
/* The generation of the dataset */
datacube(mio2eur(X)) :- datacube(X),
  dimension(X,unit), ( \+
  dimensionmember(X,unit,Z);
  dimensionmember(X,unit,mioeur) ).
/* Copying over of dimensions */
dimension(mio2eur(X), Y) :- datacube(X),
  dimension(X,unit), ( \+
  dimensionmember(X,unit,Z);
  dimensionmember(X,unit,mioeur) ),
  dimension(X,Y).
```

How to restrict the possible number of conversion and merging operations? (4)

```
/* Copying over of dimension members */
dimensionmember(mio2eur(X), Y, V) :-
  datacube(X), dimension(X,unit), ( \+
  dimensionmember(X,unit,Z);
  dimensionmember(X,unit,mioeur) ),
  dimensionmember(X,Y,V), \+
  dimensionmember(X, unit, mioeur).
/* Setting the new dimension member */
dimensionmember(mio2eur(X), unit, eur) :-
  datacube(X), dimension(X,unit), ( \+
  dimensionmember(X,unit,Z);
  dimensionmember(X,unit,mioeur) ).
```

In practice few (in GDP per Capita scenario, only 54)

Conclusions

- Many different multidimensional datasets available as **Linked Data**
- No easy querying due to **heterogeneities**
- **Global Cube** as a unified schema of all such datasets
- Pay-as-you-go integration with **two mapping** approaches

- WolframAlpha and flexibly adding data sources if
  - 1) we are able to materialise the Global Cube offline (execute queries efficiently over RDF + recognise if datasets change),
  - 2) we resolve the inherent semantic conflicts in Open Government Data

A different topic...

- Looked-up vs Computed
- 27,800 27,704

Thanks!

- Looked-up vs Computed
- 27,800 vs 27,704

eurostat

Backup: Evaluation

- Implementation in OLAP4LD [1]
  - Drill-Across (loading and query processing grow linearly)

Exper.	#DS	#T	#O	L&V	QP	T
UNEMPLOY	2	3,897	362	11	11	22
EU2020a	4	19,714	2,212	18	21	39
EU2020b	8	38,069	3,992	47	56	103

  - Convert-Cube Queries (without full materialisation)

Exper.	#DS	#T	#O	L&V	QP	T
GDP_CAP	3	1,015,044	126,351	119	127	246

[1] http://olap4ld.googlecode.com/

Backup: Two smaller problems

- Integrity constraint violations
- Open World assumption

Integrity constraint violations

```
"integrity constraint violation" :-
  ds(D1, ..., Dn, M1), ds(D1, ..., Dn,
  M2), M1 != M2.
```

Solution

Drill-Across(ds1, ds2) = ds3 with

1) If dimensions(ds1) != dimensions(ds2) then:
   dimension(ds3) = dimension(ds1) UNION dimension(ds2)
   and ds3(D1, ..., Dn, M) empty.

2) Else: ds3(D1, ..., Dn, M) :- ds1(D1, ..., Dn, M1),
   ds2(D1, ..., Dn, M2), M = f(M1, M2).

f identifying "integrity constraint violations".

Open World assumption

In Open World assumption not possible

```
ds3(D1, ..., Dn, M) :- ds1(D1, ...,
  Dn, M1), ds2(D1, ..., Dn, M2), M =
  f(M1, M2).
```

Solution

We have to assume that the dimensions are known and the relation of the multidimensional dataset fixed.