# Work at PUC


A traditional Chilean drink made with pisco (a type of brandy), lemon juice, sugar, and egg white.

Freddy

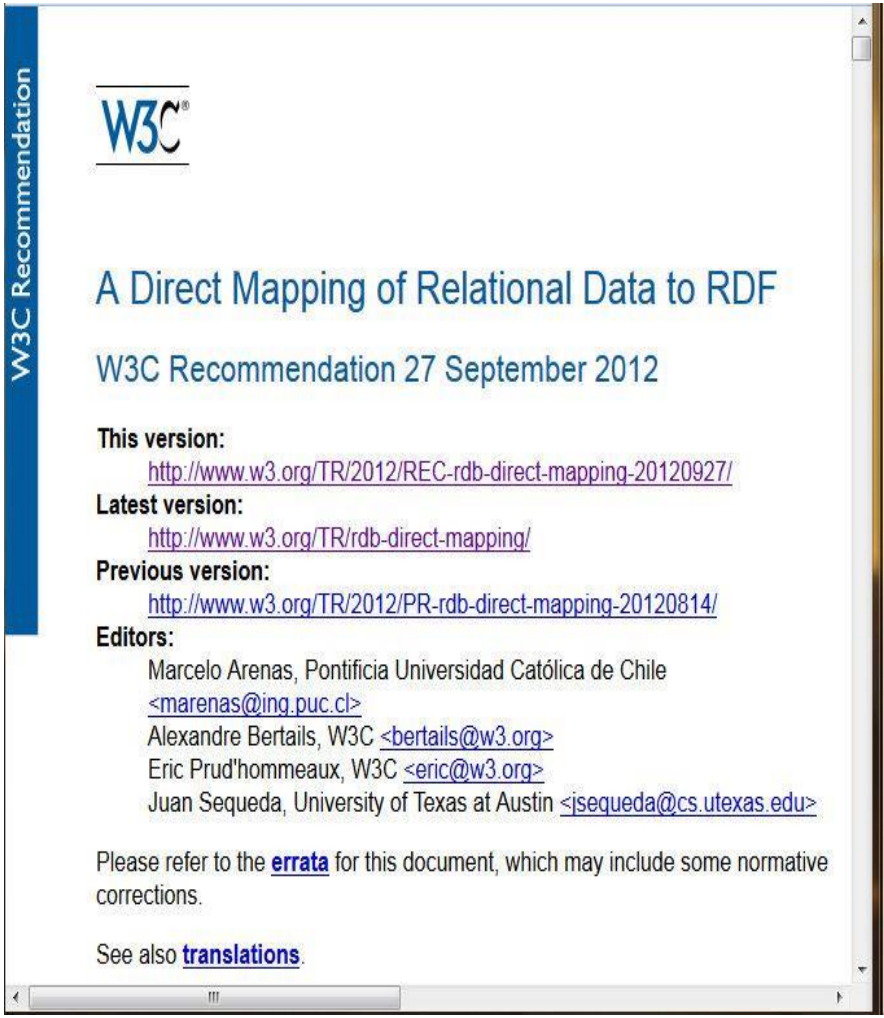
Oscr Corcho

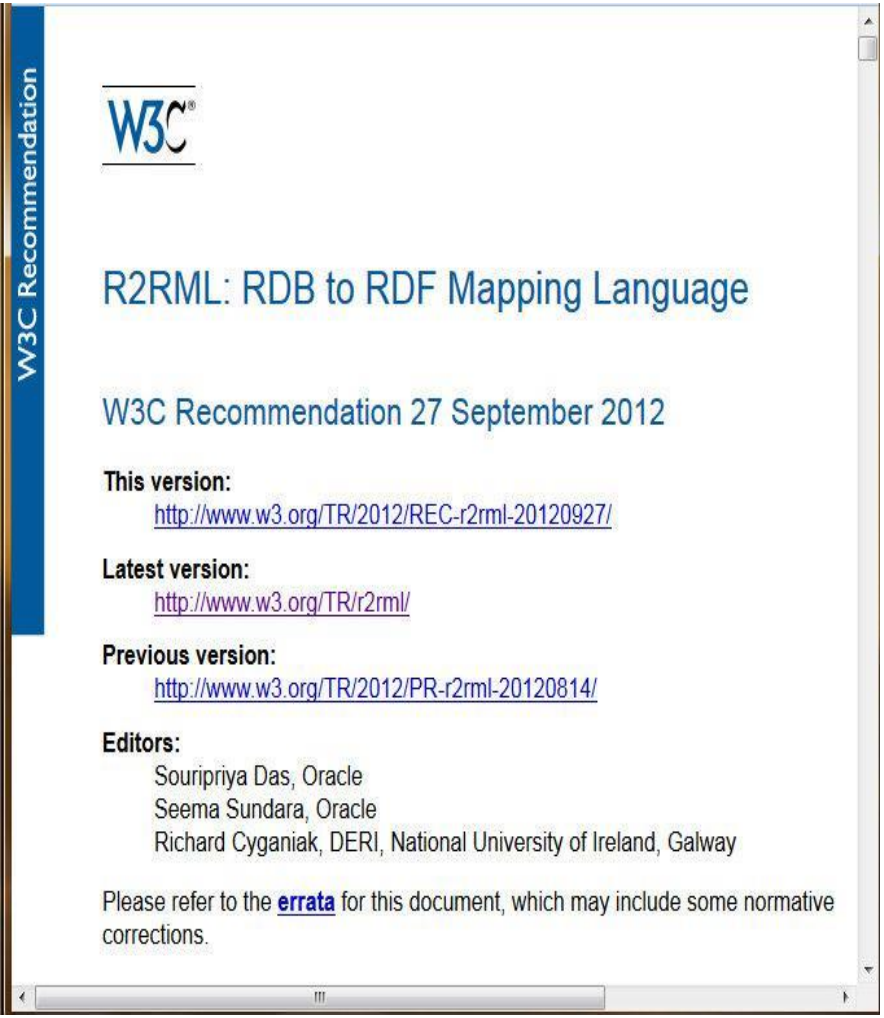
https://www.google.com/maps/@-33.4482864,-70.6534626,3a,75y,257.04h,80.36t/data=!3m4!1e1!3m2!1sdq-IAOCo7g1DK5gpHJq_Iw!2e0?hl=es-419

# The Title

- Option 1: On the Expressive Power of Direct Mapping and its Relationship with R2RML
- Option 2: Making morph-RDB out-of-business

# A Tale of Two ~~Cities~~ Recommendations



# Direct Mapping

People

| *PK* | | *→ Address(ID)* |
|---|---|---|
| **ID** | **fname** | **addr** |
| 7 | Bob | 18 |
| 8 | Sue | **NULL** |

Addresses

| *PK* | | |
|---|---|---|
| **ID** | **city** | **state** |
| 18 | Cambridge | MA |

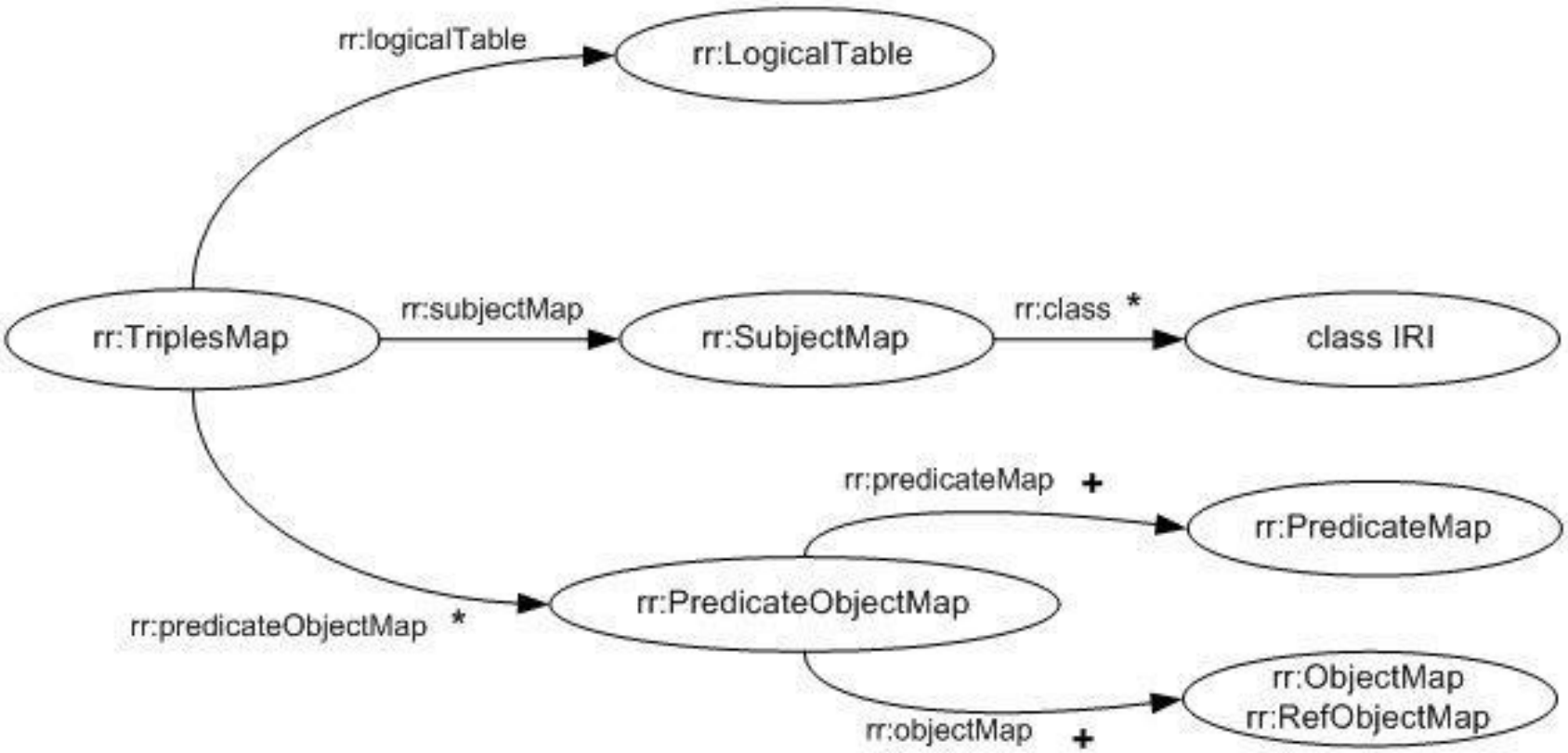
Given a base IRI `http://foo.example/DB/`, the direct mapping of this database produces a direct graph:

```
@base <http://foo.example/DB/> .
@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .


<People/ID=7> rdf:type <People> .
<People/ID=7> <People#ID> 7 .
<People/ID=7> <People#fname> "Bob" .
<People/ID=7> <People#addr> 18 .
<People/ID=7> <People#ref-addr> <Addresses/ID=18> .
<People/ID=8> rdf:type <People> .
<People/ID=8> <People#ID> 8 .
<People/ID=8> <People#fname> "Sue" .

<Addresses/ID=18> rdf:type <Addresses> .
<Addresses/ID=18> <Addresses#ID> 18 .
<Addresses/ID=18> <Addresses#city> "Cambridge" .
<Addresses/ID=18> <Addresses#state> "MA" .
```

- One-click system
- Semantics in datalog (in the spec)
- Studied Properties (Sequeda et. al. WWW 2012)

http://www.w3.org/TR/rdb-direct-mapping/

# R2RML




http://www.w3.org/TR/r2rml/

# R2RML Example

**DEPT**

| DEPTNO | DNAME | LOC |
|---|---|---|
| 10 | APPSERVER | NEW YORK |

```
<TriplesMapDept>
  rr:logicalTable [ rr:tableName "DEPT" ];

  rr:subjectMap [
    rr:template "http://data.example.com/department/{DEPTNO}";
    rr:class ex:Department; ];

  rr:predicateObjectMap [
    rr:predicateMap [ rr:constant ex:name;]
    rr:objectMap [ rr:column "DNAME"; ];

  rr:predicateObjectMap [
    rr:predicateMap [ rr:constant ex:location; ]
    rr:objectMap [ rr:column "LOC"; ]
]; .
```

```
<http://data.example.com/department/10> rdf:type ex:Department.
<http://data.example.com/department/10> ex:name "APPSERVER".
<http://data.example.com/department/10> ex:location "NEW YORK".
```

# R2RML Example

**EMP**

| EMPNO | ENAME | JOB | DEPTID |
|---|---|---|---|
| 7369 | SMITH | CLERK | 10 |

```
<TriplesMapEmp>
  rr:logicalTable [ rr:tableName "EMP" ];

  rr:subjectMap [
    rr:template "http://data.example.com/employee/{EMPNO}";
    rr:class ex:Employee; ];

  rr:predicateObjectMap [
    rr:predicateMap [ rr:constant ex:name; ]
    rr:objectMap [ rr:column "ENAME"; ];

  rr:predicateObjectMap [
    rr:predicateMap [ rr:constant ex:department; ]
    rr:objectMap [
      rr:parentTriplesMap <#TriplesMapDept>;
      rr:joinCondition [
        rr:child "DEPTID";  rr:parent "DEPTNO";
      ];
    ]
  ];.
```

```
<http://data.example.com/employee/7369> rdf:type ex:Employee.
<http://data.example.com/employee/7369> ex:name "SMITH".
<http://data.example.com/employee/7369> ex:department <http://data.example.com/department/10>.
```

# What is missing?

- Formal study of the relationship between R2RML <-> DM:
  - Expressive power
    - DM -> R2RML (obvious, next slide)
    - R2RML -> DM ( ? )
  - Fundamental properties
    - Information Preservation
    - Query Result Preservation

# Information Preservation: Example

PERSON

| PERSONID | LASTNAME |
|---|---|
| 7369 | Smith |

EMP

| PK | |
|---|---|
| **EID** | **LNAME** |
| 7369 | Smith |

```
<TMEmp> a rr:TriplesMap;
  rr:logicalTable [ rr:tableName “EMP” ];

  rr:subjectMap [
    rr:template “:PERSON/PERSONID={EID}.LASTNAME={LNAME}”;
    rr:class PERSON; rr:termType rr:blankNode;
  ];

  rr:predicateObjectMap [
    rr:predicateMap [ rr:constant PERSON#PERSONID];
    rr:objectMap [ rr:column "EID"];
  ];

  rr:predicateObjectMap [
    rr:predicateMap [ rr:constant PERSON#LASTNAME];
    rr:objectMap [ rr:column "LNAME"];
  ]
].
```

W3C

A Direct Mapping of Relational Data to RDF

W3C

R2RML: RDB to RDF Mapping Language

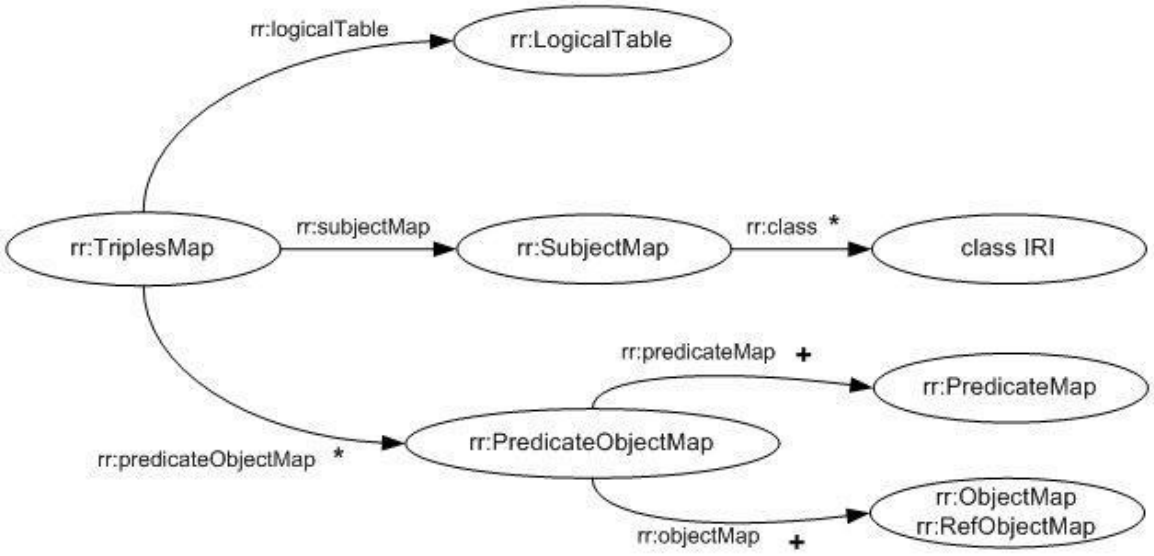
```
:PERSON/PERSONID=7369.LASTNAME=Smith rdf:type <PERSON> .
:PERSON/PERSONID=7369.LASTNAME=Smith <PERSON#PERSONID> "7369" .
:PERSON/PERSONID=7369.LASTNAME=Smith <PERSON#LASTNAME> "Smith" .
```

# Preliminaries

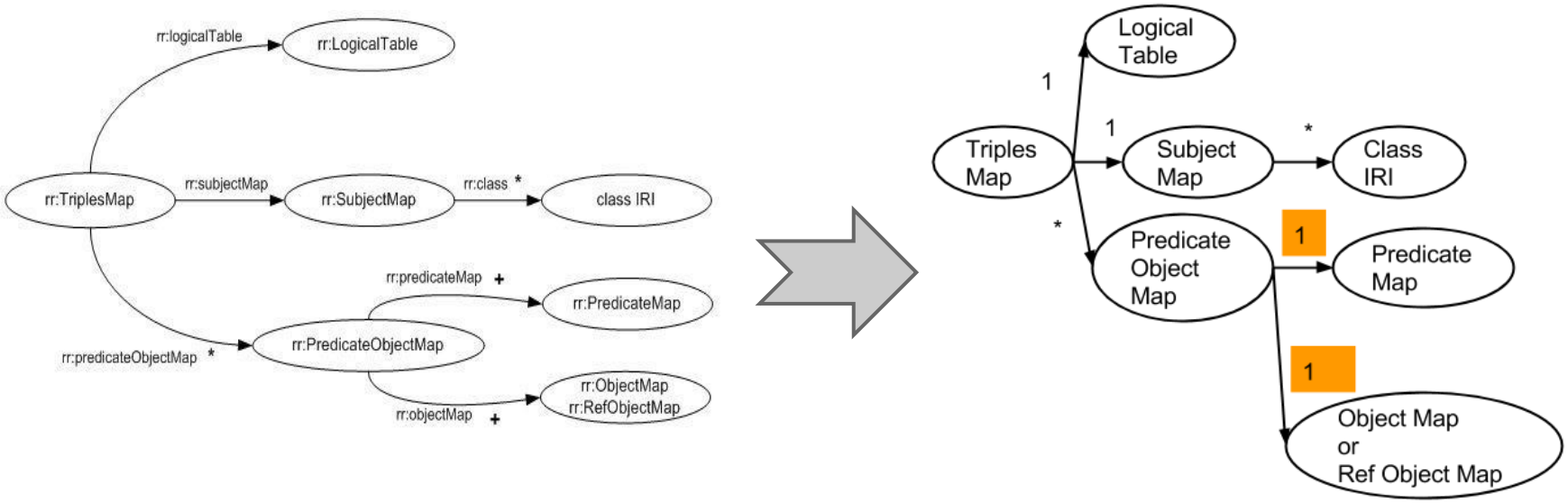
- Database schema: *R*
- Database instance: *I*
- SQL query: *Q*
- View Definition $V_Q^{\mathbf{R}}$ is a query *Q* over *R*
- View $V_Q^I$ is the result of query evaluation *Q* over *I*
- Direct Mapping: *DM*
- R2RML Mapping Document: *M*
- *M* evaluated over *I*: $[[M]]_I$
- *DM* evaluated over *I*: $[[DM]]_I$
- Substitution: $\sigma$
- SPARQL Query: $P$, $P_1$, $P_2$

# Preliminaries
# R2RML$_{Lite}$

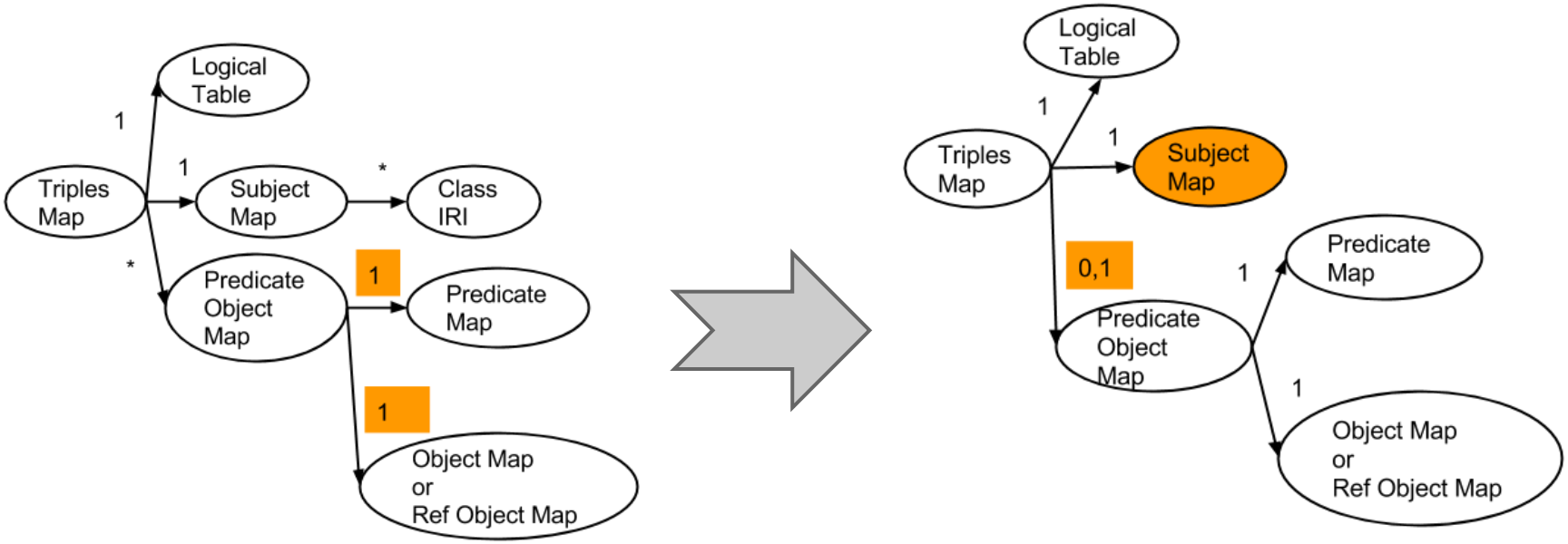
- no termtype (blanknode, literal,IRI)
- no datatype (xsd:dateTime, xsd:positiveInteger, etc)
- no language tag (english, spanish, etc)



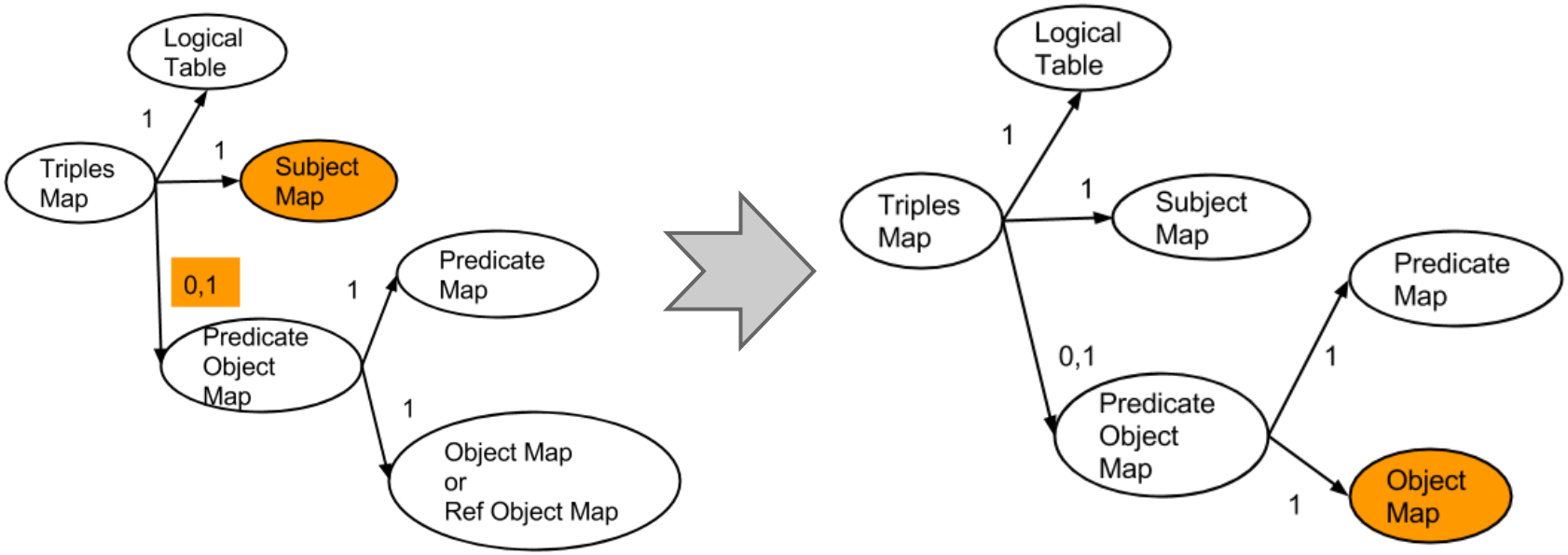
# Preliminaries
# R2RML Mappings 1st Normal Form



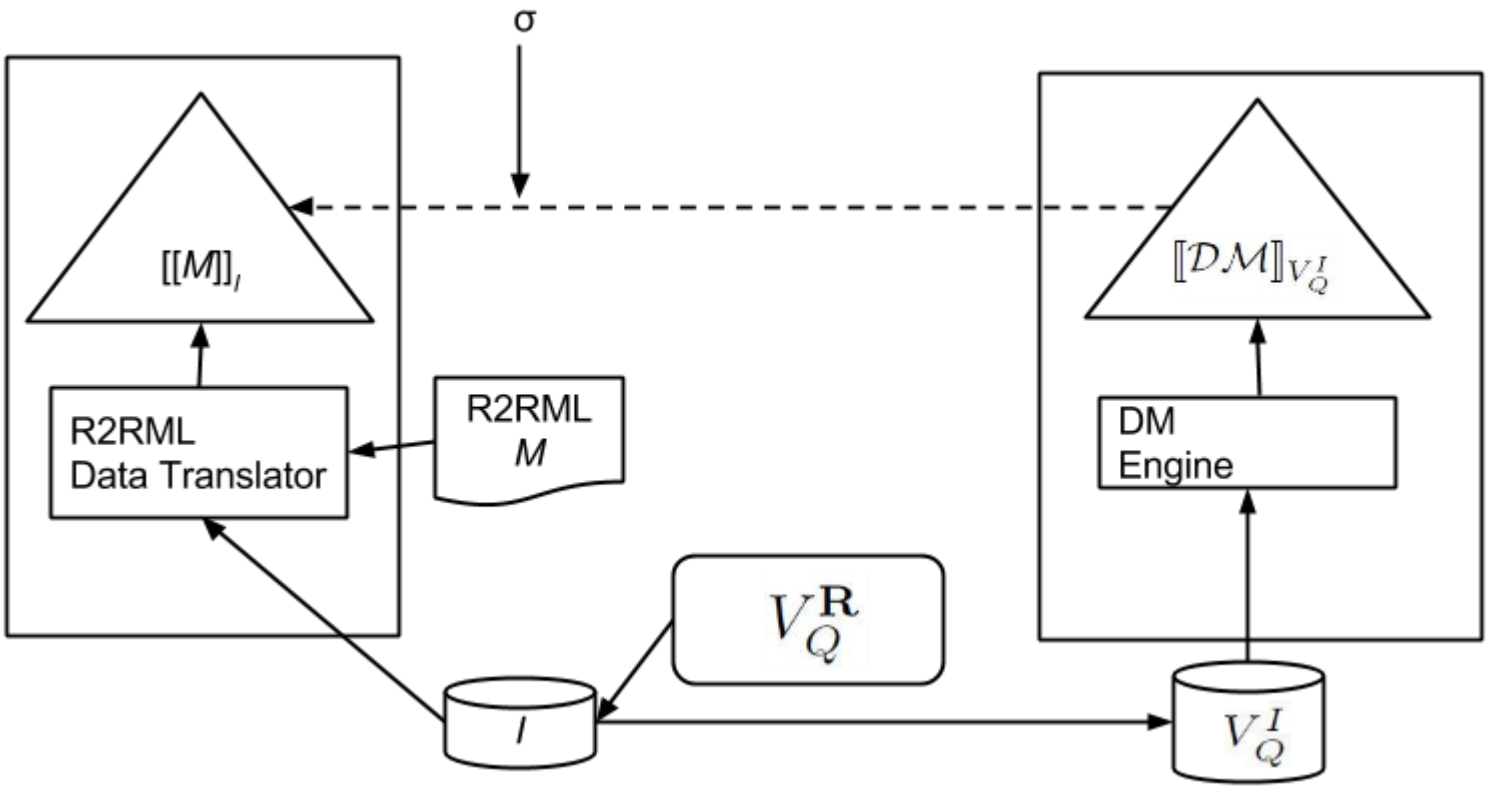
# Preliminaries
# R2RML Mappings 2nd Normal Form



# Preliminaries
# R2RML Mappings 3rd Normal Form

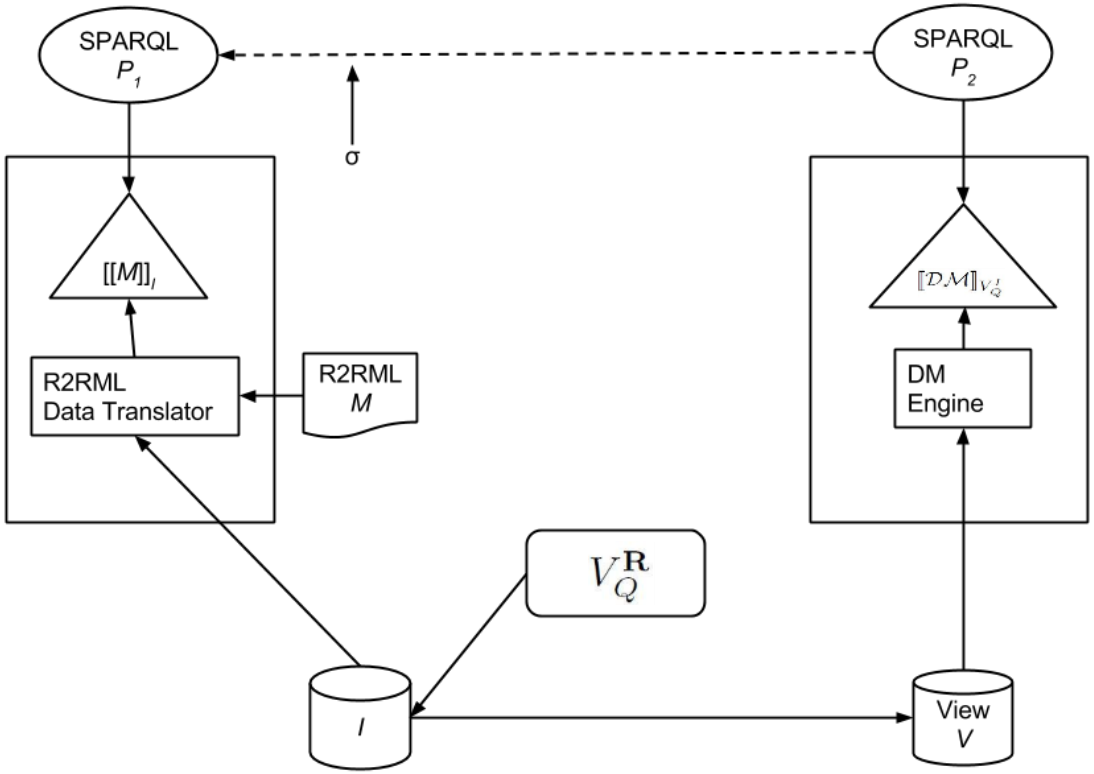


# Information Preservation (IP) of View Definitions



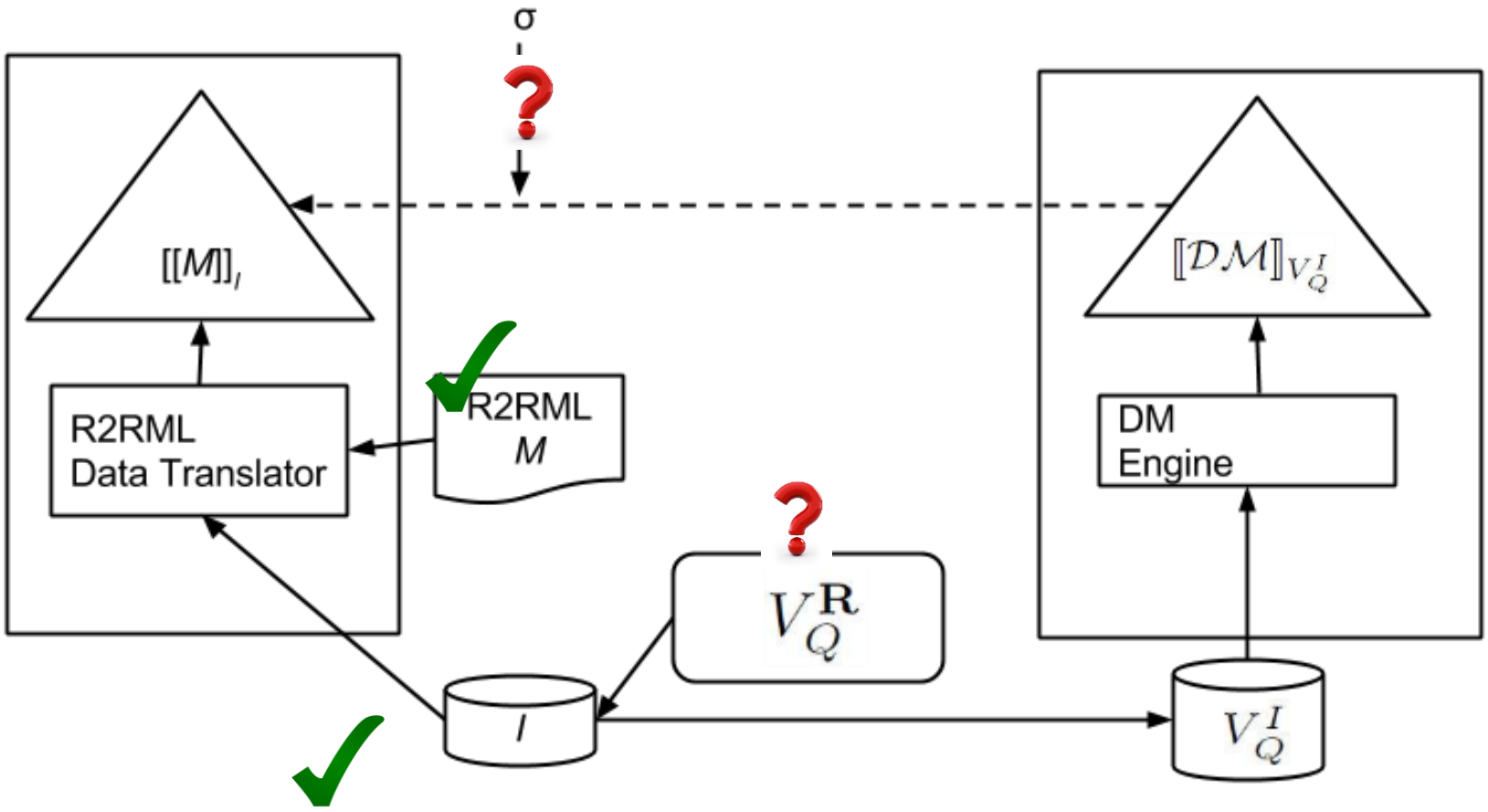

**Definition 1 (Information preservation)** *A view definition* $V_Q^{\mathrm{R}}$ *over a relational schema* $\mathbf{R}$ *is information preserving with respect to R2RML mapping document* $\mathcal{M}$ *if for every instance* $I$ *of* $\mathbf{R}$*, there exists a substitution* $\sigma$*, such that* $[\![\mathcal{M}]\!]_I = \sigma([\![\mathcal{DM}]\!]_{V_Q^I})$.

# Query Result Preservation (QRP) of View Definitions



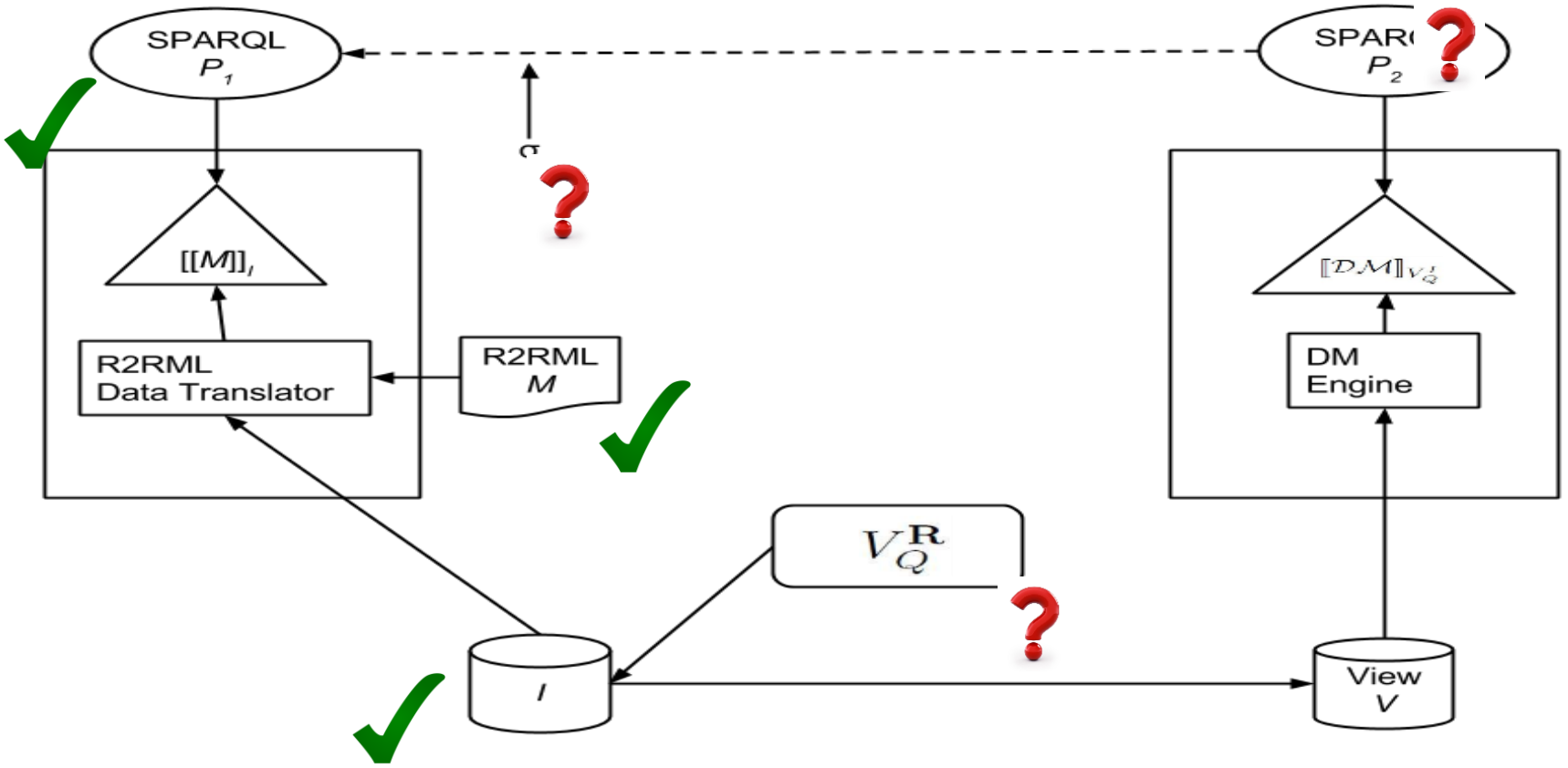

**Definition 2 (Query result preservation)** *A view definition $V_Q^{\mathbf{R}}$ is query result preserving with respect to R2RML mapping document $\mathcal{M}$ if for every SPARQL query $P_1$, there exists a SPARQL query $P_2$, such that for every instance $I$ of $\mathbf{R}$, there exists a substitution $\sigma$ satisfying the following condition:* $[\![P_1]\!]_{[\![M]\!]_I} = \sigma([\![P_2]\!]_{[\![\mathcal{DM}]\!]_{V_Q^I}})$.

# IP Problem (IPP)




Given a relational schema *R* and R2RML mapping document *M*, find substitution $\sigma$ and query $V_Q^{\mathbf{R}}$ that satisfy the Information Preservation Property

# QRP Problem




Given a relational schema *R*, an R2RML mapping document *M*. and a query $P_1$, find substitution $\sigma$ , view definition $V_Q^{\mathbf{R}}$ , and query $P_2$ that satisfy the Query Result Preservation Property

# Running Example

EMP

| PK | | | | -> DEPT (DID) |
|---|---|---|---|---|
| **EID** | **LNAME** | **FNAME** | **JOB** | **DEPTID** |
| 7369 | Smith | Adam | Clerk | 10 |

DEPT

| PK | | |
|---|---|---|
| **DID** | **DNAME** | **LOC** |
| 10 | AppServer | New York |

$I$

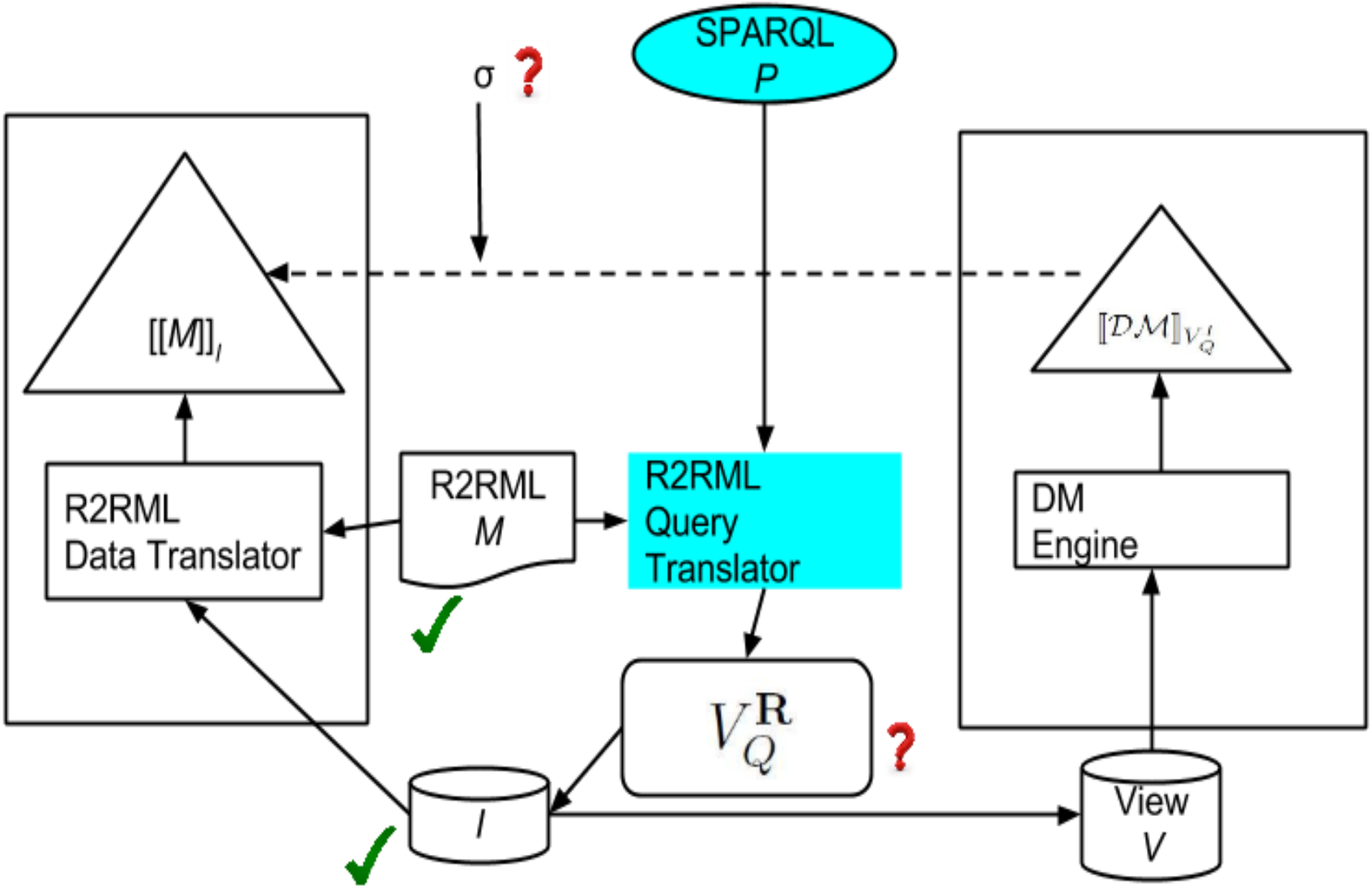
$\mathcal{M}$

```
<TMEmployee> a rr:TriplesMap;
  rr:logicalTable [ rr:tableName  "EMP" ];

  rr:subjectMap [
    rr:template "http://ex.com/Person/{EID}";
    rr:class ex:Employee
  ];

  rr:predicateObjectMap [
    rr:predicateMap [ rr:constant ex:name ];
    rr:objectMap [ rr:column "LNAME"; ];
    rr:objectMap [ rr:column "FNAME"; ];
  ];

  rr:predicateObjectMap [
    rr:predicateMap [ rr:constant ex:fullname];
    rr:objectMap [ rr:template "{LNAME},{FNAME}"; ];
  ];

  rr:predicateObjectMap [
    rr:predicateMap [ rr:constant ex:worksIn];
    rr:objectMap [
      rr:parentTriplesMap <TMDepartment>;
      rr:joinCondition [ rr:child "DEPTID" ; rr:parent "DID" ; ]
    ];
].

<TMDepartment> a rr:TriplesMap;
  rr:logicalTable [ rr:tableName  "DEPT" ];

  rr:subjectMap [
    rr:template "http://ex.com/Department/{DID}{DNAME}";
    rr:class ex:Department
  ];

  rr:predicateObjectMap [
    rr:predicateMap [ rr:constant ex:name ];
    rr:objectMap [ rr:column "DNAME"; ];
  ];
].
```

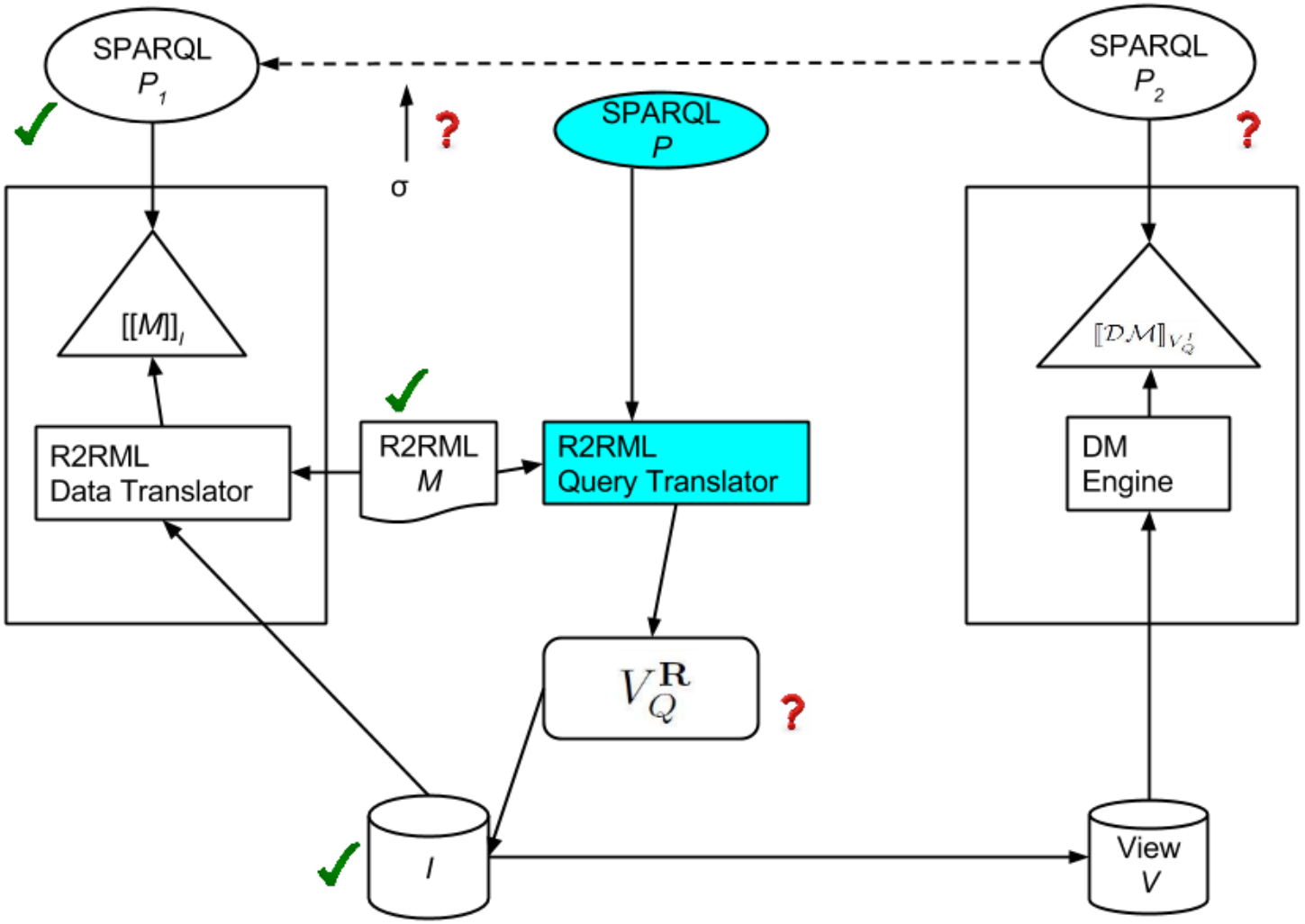
$[\![\mathcal{M}]\!]_I$

<http://ex.com/Person/7369> rdf:type ex:Employee.
<http://ex.com/Person/7369> ex:name "SMITH".
<http://ex.com/Person/7369> ex:name "ADAM".
<http://ex.com/Person/7369> ex:fullname "SMITH,ADAM".
<http://ex.com/Person/7369> ex:worksIn <http://ex.com/Department/10APPSERVER>.
<http://ex.com/Department/10APPSERVER> rdf:type ex:Department.
<http://ex.com/Department/10APPSERVER> ex:name "APPSERVER".

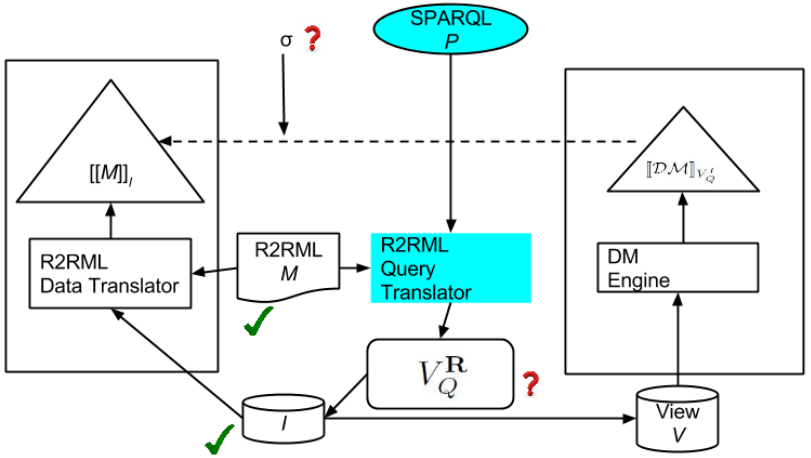
# Our Approach for Solving the IP Problem



# Our Approach for Solving QRP Problem

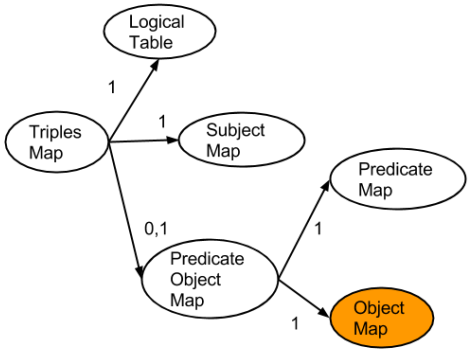


# IP Problem
# Vertical Approach




1. Normalize mappings in $M_{Lite}$ form to $M$ where $M$ is in 3rd NF
2. Set $Q$ = *trans(P, M)*
   - $P$ = `SELECT ?s AS ?rdf:subject ?p AS ?rdf:predicate ?o AS ?rdf:object WHERE { ?s ?p ?o }.`
3. Set $V_Q^{\mathbf{R}}$ = `CREATE VIEW rdf:statement AS` $Q$`;`
4. Set $\sigma$ =
   - Replace `rdf:Statement#rdf:subject` with `rdf:subject`
   - Replace `rdf:Statement#rdf:predicate` with `rdf:predicate`
   - Replace `rdf:Statement#rdf:object` with `rdf:object`

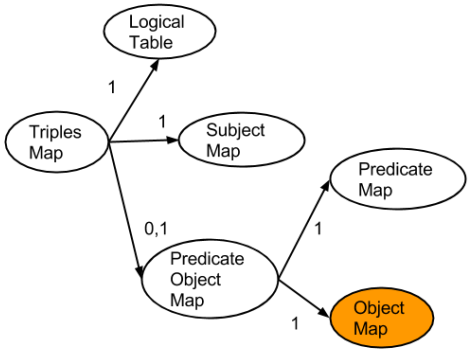
# IP Problem
# Approach - Step 1
# Normalize Mappings




```
<TMEmployee> a rr:TriplesMap;
  rr:logicalTable [ rr:tableName  "EMP" ];

  rr:subjectMap [
    rr:template "http://ex.com/Person/{EID}";
    rr:class ex:Employee
  ];

  rr:predicateObjectMap [
    rr:predicateMap [ rr:constant ex:name ];
    rr:objectMap [ rr:column "LNAME"; ];
    rr:objectMap [ rr:column "FNAME"; ];
  ];

  rr:predicateObjectMap [
    rr:predicateMap [ rr:constant ex:fullname];
    rr:objectMap [ rr:template "{LNAME},{FNAME}"; ];
  ];

  rr:predicateObjectMap [
    rr:predicateMap [ rr:constant ex:worksIn];
    rr:objectMap [
      rr:parentTriplesMap <TMDepartment>;
      rr:joinCondition [ rr:child "DEPTID" ; rr:parent "DID" ; ]
    ];
].
```

```
<TMEmployee1> a rr:TriplesMap;
  rr:logicalTable [ rr:tableName  "EMP" ];
  rr:subjectMap [ rr:template "http://ex.com/Person/{EID}";  ];
  rr:predicateObjectMap [
    rr:predicateMap [rr:constant rdf:type]; rr:objectMap [rr:constant ex:Employee];
  ]; ];

<TMEmployee2> a rr:TriplesMap;
  rr:logicalTable [ rr:tableName  "EMP" ];
  rr:subjectMap [ rr:template "http://ex.com/Person/{EID}";  ];
  rr:predicateObjectMap [
    rr:predicateMap [ rr:constant ex:name ]; rr:objectMap [ rr:column "LNAME"; ];
  ]; ];

<TMEmployee3> a rr:TriplesMap;
  rr:logicalTable [ rr:tableName  "EMP" ];
  rr:subjectMap [ rr:template "http://ex.com/Person/{EID}";  ];
  rr:predicateObjectMap [
    rr:predicateMap [ rr:constant ex:name ]; rr:objectMap [ rr:column "FNAME"; ];
  ]; ];

<TMEmployee4> a rr:TriplesMap;
  rr:logicalTable [ rr:tableName  "EMP" ];
  rr:subjectMap [ rr:template "http://ex.com/Person/{EID}";  ];
  rr:predicateObjectMap [
    rr:predicateMap[rr:constant ex:name];rr:objectMap[rr:template "{LNAME},{FNAME}";];
  ]; ];

<TMEmployee5> a rr:TriplesMap;
  rr:logicalTable [ rr:sqlQuery  """SELECT EMP.EID, DEPT.DID, DEPT.DNAME FROM EMP JOIN
DEPT ON EMP.DEPTID = DEPT.DID""" ];
  rr:subjectMap [ rr:template "http://ex.com/Person/{EID}";  ];
  rr:predicateObjectMap [
    rr:predicateMap [rr:constant ex:worksIn];
    rr:objectMap [rr:template "http://ex.com/Department/{DID}{DNAME}"];
  ]; ].
```

# IP Problem Approach - Step 1 Normalize Mappings



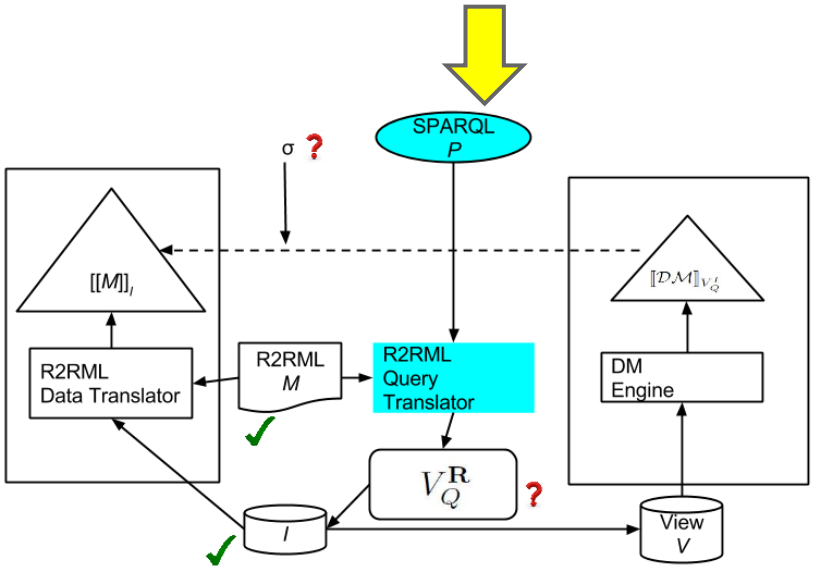

```
<TMDepartment> a rr:TriplesMap;
  rr:logicalTable [ rr:tableName  "DEPT" ];

  rr:subjectMap [
    rr:template "http://ex.com/Department/{DID}{DNAME}";
    rr:class ex:Department
  ];

  rr:predicateObjectMap [
    rr:predicateMap [ rr:constant ex:name ];
    rr:objectMap [ rr:column "DNAME"; ];
  ];
].
```

```
<TMDepartment_1> a rr:TriplesMap;
  rr:logicalTable [ rr:tableName  "DEPT" ];
  rr:subjectMap [ rr:template "http://ex.com/Department/{DID}{DNAME}"; ];
  rr:predicateObjectMap [
   rr:predicateMap [rr:constant rdf:type];rr:objectMap [rr:constant ex:Department;];
  ]; ].

<TMDepartment_2> a rr:TriplesMap;
  rr:logicalTable [ rr:tableName  "DEPT" ];
  rr:subjectMap [ rr:template "http://ex.com/Department/{DID}{DNAME}"; ];
  rr:predicateObjectMap [
   rr:predicateMap [rr:constant ex:name]; rr:objectMap [rr:column "DNAME";];
  ]; ].
```

# IP Problem Approach - Step 2 Generating Q

Set *Q* = *trans(P, M)*

*P* =
```
SELECT
    ?s AS ?rdf:subject
    ?p AS ?rdf:predicate
    ?o AS ?rdf:object
WHERE { ?s ?p ?o }.
```



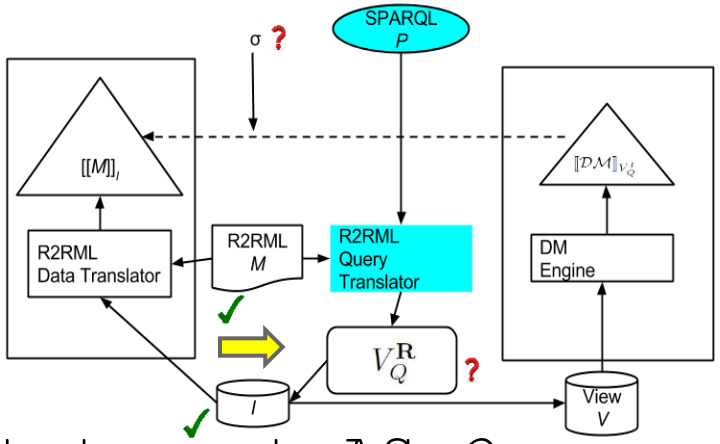

```
Q = TRANS(P, M) =
SELECT
       CONCAT("ex.com/Person/", EID) AS rdf:subject,
       "rdf:type" AS rdf:predicate,
       "ex:Employee" as rdf:object
FROM EMP
UNION
SELECT
       CONCAT("ex.com/Person/", EID) AS rdf:subject,
       "ex:name" AS rdf:predicate,
       LNAME as rdf:object
FROM EMP WHERE LNAME IS NOT NULL
UNION
SELECT
       CONCAT("ex.com/Person/", EID) AS rdf:subject,
       "ex:name" AS rdf:predicate,
       FNAME as rdf:object
FROM EMP WHERE FNAME IS NOT NULL
UNION
SELECT
       CONCAT("ex.com/Person/", EID) AS rdf:subject,
       "ex:fullname" AS rdf:predicate,
       CONCAT(LNAME, ",", FNAME) as rdf:object
FROM EMP WHERE LNAME IS NOT NULL AND FNAME IS NOT NULL
UNION

SELECT
       CONCAT("ex.com/Person/", EMP.EID) AS rdf:subject,
       "ex:worksIn" AS rdf:predicate,
       CONCAT("ex.com/Department/", DEPT.DID,DEPT.DNAME) as rdf:object
FROM EMP JOIN DEPT ON EMP.DEPTID = DEPT.DID
WHERE EMP.DEPTID IS NOT NULL AND DEPT.DNAME IS NOT NULL
UNION
SELECT
       CONCAT("ex.com/Department/", DID, DNAME) AS rdf:subject,
       "rdf:type" AS rdf:predicate,
       "ex:Department" as rdf:object
FROM DEPT WHERE DNAME IS NOT NULL
UNION
SELECT
       CONCAT("ex.com/Department/", DID, DNAME) AS rdf:subject,
       "ex:name" AS rdf:predicate,
       DNAME as rdf:object
FROM DEPT WHERE DNAME IS NOT NULL;
```

# IP Problem Approach - Step 2 Generating Q

```
<TMEmployee1> a rr:TriplesMap;
  rr:logicalTable [ rr:tableName  "EMP" ];
  rr:subjectMap [ rr:template "http://ex.com/Person/{EID}";  ];
  rr:predicateObjectMap [
    rr:predicateMap [rr:constant rdf:type]; rr:objectMap [rr:constant ex:Employee];
  ]; ];

<TMEmployee2> a rr:TriplesMap;
  rr:logicalTable [ rr:tableName  "EMP" ];
  rr:subjectMap [ rr:template "http://ex.com/Person/{EID}";  ];
  rr:predicateObjectMap [
    rr:predicateMap [ rr:constant ex:name ]; rr:objectMap [ rr:column "LNAME"; ];
  ]; ];

<TMEmployee3> a rr:TriplesMap;
  rr:logicalTable [ rr:tableName  "EMP" ];
  rr:subjectMap [ rr:template "http://ex.com/Person/{EID}";  ];
  rr:predicateObjectMap [
    rr:predicateMap [ rr:constant ex:name ]; rr:objectMap [ rr:column "FNAME"; ];
  ]; ];

<TMEmployee4> a rr:TriplesMap;
  rr:logicalTable [ rr:tableName  "EMP" ];
  rr:subjectMap [ rr:template "http://ex.com/Person/{EID}";  ];
  rr:predicateObjectMap [
    rr:predicateMap[rr:constant ex:name];rr:objectMap[rr:template "{LNAME},{FNAME}";];
  ]; ];

<TMEmployee5> a rr:TriplesMap;
  rr:logicalTable [ rr:sqlQuery  """SELECT EMP.EID, DEPT.DID, DEPT.DNAME FROM EMP JOIN
DEPT ON EMP.DEPTID = DEPT.DID""" ];
  rr:subjectMap [ rr:template "http://ex.com/Person/{EID}";  ];
  rr:predicateObjectMap [
    rr:predicateMap [rr:constant ex:worksIn];
    rr:objectMap [rr:template "http://ex.com/Department/{DID}{DNAME}"];
  ]; ].

<TMDepartment1> a rr:TriplesMap;
```

```
Q = TRANS(P, M) =
SELECT
      CONCAT("ex.com/Person/", EID) AS rdf:subject,
      "rdf:type" AS rdf:predicate,
      "ex:Employee" as rdf:object
FROM EMP
UNION
SELECT
      CONCAT("ex.com/Person/", EID) AS rdf:subject,
      "ex:name" AS rdf:predicate,
      LNAME as rdf:object
FROM EMP WHERE LNAME IS NOT NULL
UNION
SELECT
      CONCAT("ex.com/Person/", EID) AS rdf:subject,
      "ex:name" AS rdf:predicate,
      FNAME as rdf:object
FROM EMP WHERE FNAME IS NOT NULL
UNION
SELECT
      CONCAT("ex.com/Person/", EID) AS rdf:subject,
      "ex:fullname" AS rdf:predicate,
      CONCAT(LNAME, ",", FNAME) as rdf:object
FROM EMP WHERE LNAME IS NOT NULL AND FNAME IS NOT NU
UNION

SELECT
      CONCAT("ex.com/Person/", EMP.EID) AS rdf:subj
      "ex:worksIn" AS rdf:predicate,
      CONCAT("ex.com/Department/", DEPT.DID,DEPT.DN
FROM EMP JOIN DEPT ON EMP.DEPTID = DEPT.DID
WHERE EMP.DEPTID IS NOT NULL AND DEPT.DNAME IS NOT N
UNION
SELECT
      CONCAT("ex.com/Department/", DID, DNAME) AS r
      "rdf:type" AS rdf:predicate,
      "ex:Department" as rdf:object
```

# IP Problem Approach - Step 3 Generating View

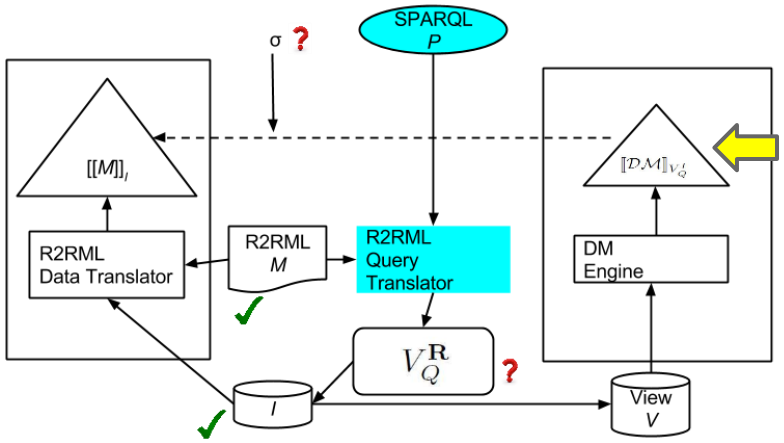



Set $V_Q^{\mathbf{R}}$ = `CREATE VIEW rdf:statement AS Q;`

**rdf:Statement** $V_Q^I$

| rdf:subject | rdf:predicate | rdf:object |
|---|---|---|
| ex.com/Person/7369 | rdf:type | ex:Employee |
| ex.com/Person/7369 | ex:name | SMITH |
| ex.com/Person/7369 | ex:name | ADAM |
| ex.com/Person/7369 | ex:fullname | SMITH,ADAM |
| ex.com/Person/7369 | ex:worksIn | ex.com/Department/10APPSERVER |
| ex.com/Department/10APPSERVER | rdf:type | ex:Department |
| ex.com/Department/10APPSERVER | ex:name | APPSERVER |

# IP Problem Approach - Step 3
# DM Evaluation




:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=rdf:type.rdf:object=ex:Employee rdf:type rdf:Statement.
:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=rdf:type.rdf:object=ex:Employee rdf:Statement#rdf:subject ex.com/Person/7369.
:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=rdf:type.rdf:object=ex:Employee rdf:Statement#rdf:predicate rdf:type.
:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=rdf:type.rdf:object=ex:Employee rdf:Statement#rdf:object ex:Employee.

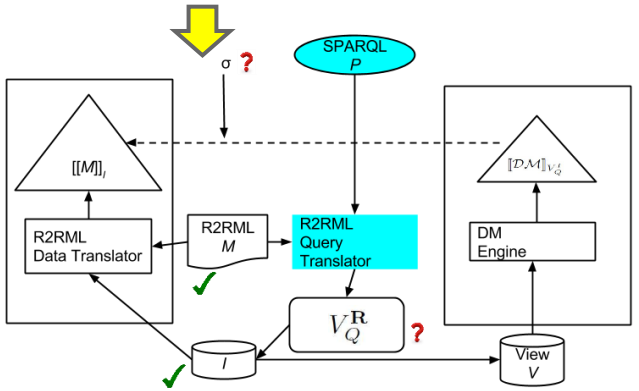
:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=ex:name.rdf:object=SMITH rdf:type rdf:Statement.
:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=ex:name.rdf:object=SMITH rdf:Statement#rdf:subject ex.com/Person/7369.
:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=ex:name.rdf:object=SMITH rdf:Statement#rdf:predicate ex:name.
:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=ex:name.rdf:object=SMITH rdf:Statement#rdf:object “SMITH”.

$[\![\mathcal{DM}]\!]_{V_Q^I}$

:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=ex:name.rdf:object=ADAM rdf:type rdf:Statement.
:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=ex:name.rdf:object=ADAM rdf:Statement#rdf:subject ex.com/Person/7369.
:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=ex:name.rdf:object=ADAM rdf:Statement#rdf:predicate ex:name.
:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=ex:name.rdf:object=ADAM rdf:Statement#rdf:object “ADAM”.

:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=ex:fullname.rdf:object=SMITH,ADAM rdf:type rdf:Statement.
:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=ex:fullname.rdf:object=SMITH,ADAM rdf:Statement#rdf:subject ex.com/Person/7369.
:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=ex:fullname.rdf:object=SMITH,ADAM rdf:Statement#rdf:predicate ex:fullname.

# IP Problem Approach - Step 4 Substitution



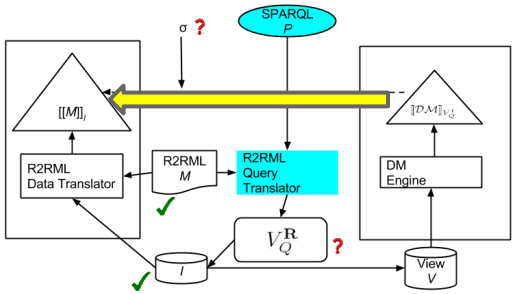

Set $\sigma$ =

- Replace `rdf:Statement#rdf:subject` with `rdf:subject`
- Replace `rdf:Statement#rdf:predicate` with `rdf:predicate`
- Replace `rdf:Statement#rdf:object` with `rdf:object`

```
:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=rdf:type.rdf:object=ex:Employee rdf:type rdf:Statement.
:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=rdf:type.rdf:object=ex:Employee rdf:subject ex.com/Person/7369.
:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=rdf:type.rdf:object=ex:Employee rdf:predicate rdf:type.
:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=rdf:type.rdf:object=ex:Employee rdf:object ex:Employee.

:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=ex:name.rdf:object=SMITH rdf:type rdf:Statement.
:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=ex:name.rdf:object=SMITH rdf:subject ex.com/Person/7369.
:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=ex:name.rdf:object=SMITH rdf:predicate ex:name.
:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=ex:name.rdf:object=SMITH rdf:object “SMITH”.

:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=ex:name.rdf:object=ADAM rdf:type rdf:Statement.
:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=ex:name.rdf:object=ADAM rdf:subject ex.com/Person/7369.
:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=ex:name.rdf:object=ADAM rdf:predicate ex:name.
:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=ex:name.rdf:object=ADAM rdf:object “ADAM”.

:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=ex:fullname.rdf:object=SMITH,ADAM rdf:type rdf:Statement.
:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=ex:fullname.rdf:object=SMITH,ADAM rdf:subject ex.com/Person/7369.
:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=ex:fullname.rdf:object=SMITH,ADAM rdf:predicate ex:name.
:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=ex:fullname.rdf:object=SMITH ADAM rdf:object “SMITH ADAM”.
```

$$\sigma([\![\mathcal{DM}]\!]_{V_Q^I})$$

# IP Problem Solved




<http://ex.com/Person/7369> rdf:type ex:Employee.
<http://ex.com/Person/7369> ex:name "SMITH".
<http://ex.com/Person/7369> ex:name "ADAM".
<http://ex.com/Person/7369> ex:fullname "SMITH,ADAM".
<http://ex.com/Person/7369> ex:worksIn <http://ex.com/Department/10APPSERVER>.
<http://ex.com/Department/10APPSERVER> rdf:type ex:Department.
<http://ex.com/Department/10APPSERVER> ex:name "APPSERVER".

$$[\![\mathcal{M}]\!]_I$$

$$\sigma([\![\mathcal{DM}]\!]_{V_Q^I})$$

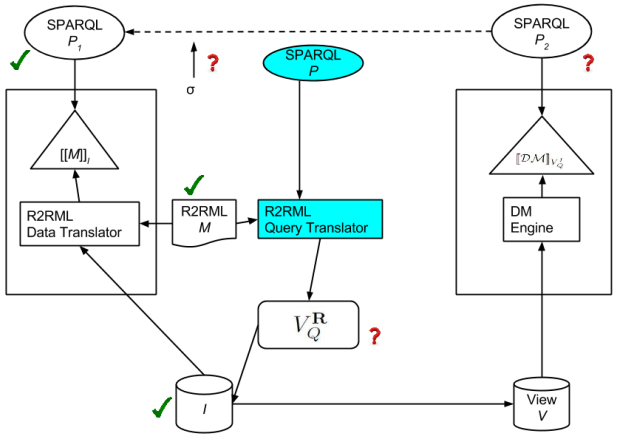
:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=rdf:type.rdf:object=ex:Employee rdf:type rdf:Statement.
:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=rdf:type.rdf:object=ex:Employee rdf:subject ex.com/Person/7369.
:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=rdf:type.rdf:object=ex:Employee rdf:predicate rdf:type.
:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=rdf:type.rdf:object=ex:Employee rdf:object ex:Employee.

:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=ex:name.rdf:object=SMITH rdf:type rdf:Statement.
:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=ex:name.rdf:object=SMITH rdf:subject ex.com/Person/7369.
:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=ex:name.rdf:object=SMITH rdf:predicate ex:name.
:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=ex:name.rdf:object=SMITH rdf:object “SMITH”.

:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=ex:name.rdf:object=ADAM rdf:type rdf:Statement.
:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=ex:name.rdf:object=ADAM rdf:subject ex.com/Person/7369.
:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=ex:name.rdf:object=ADAM rdf:predicate ex:name.
:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=ex:name.rdf:object=ADAM rdf:object “ADAM”.

:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=ex:fullname.rdf:object=SMITH,ADAM rdf:type rdf:Statement.
:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=ex:fullname.rdf:object=SMITH,ADAM rdf:subject ex.com/Person/7369
:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=ex:fullname.rdf:object=SMITH,ADAM rdf:predicate ex:name.

# QRP Problem
# Vertical Approach

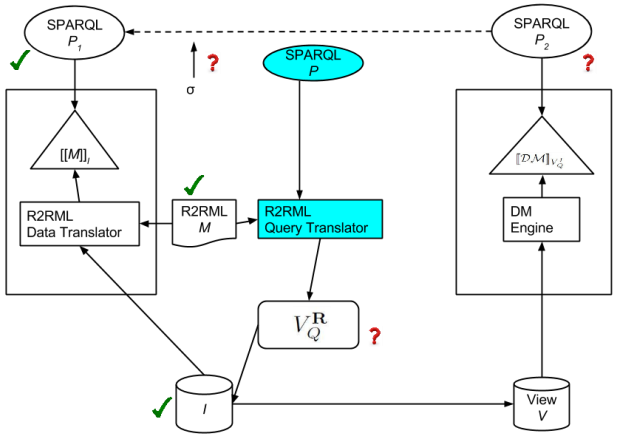



1. Normalize mappings in $M_{Lite}$ form to $M$ where $M$ is in 3rd NF
2. Set $Q$ = *trans(P, M)*
   - $P$ = `SELECT ?s AS ?rdf:subject ?p AS rdf:predicate ?o AS rdf:object WHERE { ?s ?p ?o }.`
3. Set $V_Q^{\mathbf{R}}$ = `CREATE VIEW rdf:statement AS` $Q$;
4. Set $\sigma$ = {}
5. For $P_1$ = `SELECT ?s ?p ?o WHERE {?s ?p ?o}`

set $P_2$ = `SELECT ?s ?p ?o WHERE {`

```
?st a rdf:Statement .
?st rdf:Statement#rdf:subject ?s .
?st rdf:Statement#rdf:predicate ?p .
?st rdf:Statement#rdf:object ?o .}
```

# QRP Problem Approach - Step 1-3

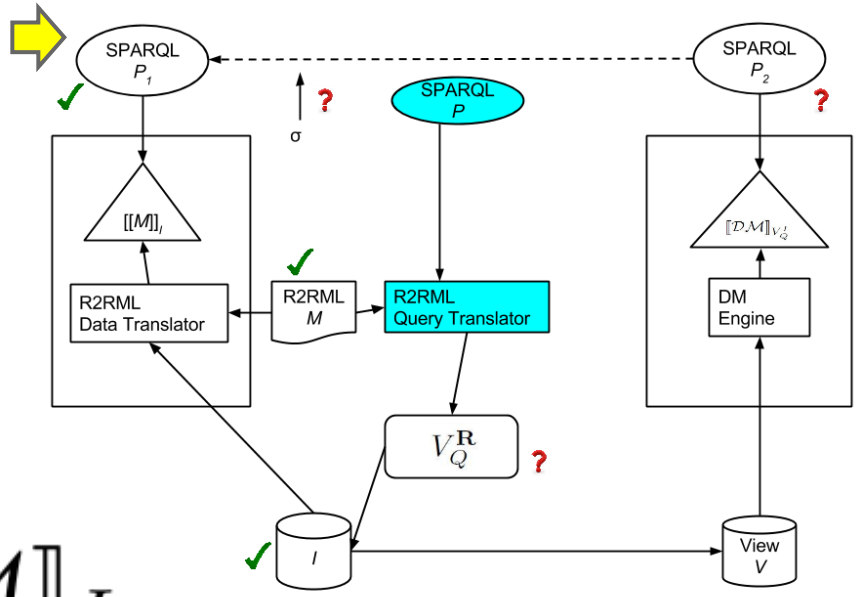



Same as IPP Approach 1 Step 1-3

1. Normalize $M_{Core}$ to $M$ where $M$ is in 3rd NF
2. Set $Q$ = *trans(P, M)*
   - $P_{V_Q^R}$ `SELECT ?s AS ?rdf:subject ?p AS rdf:predicate ?o AS rdf:object WHERE { ?s ?p ?o }.`
3. Set = `CREATE VIEW rdf:statement AS` $Q$`;`

# QRP Problem Approach - Step 4 ($P_1$)

$P_1$ = `SELECT ?s ?p ?o WHERE {?s ?p ?o}`



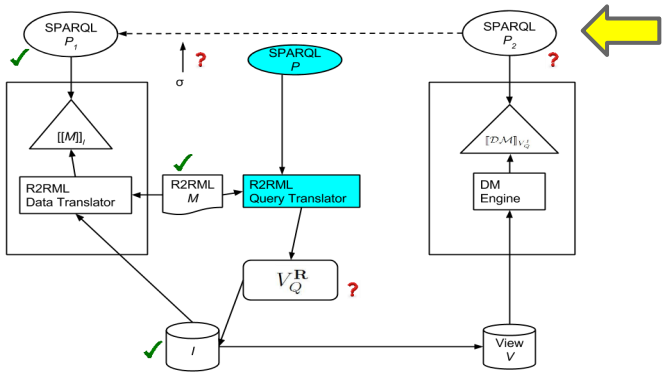

$[\![\mathcal{M}]\!]_I$

<http://ex.com/Person/7369> rdf:type ex:Employee.
<http://ex.com/Person/7369> ex:name "SMITH".
<http://ex.com/Person/7369> ex:name "ADAM".
<http://ex.com/Person/7369> ex:fullname "SMITH,ADAM".
<http://ex.com/Person/7369> ex:worksIn <http://ex.com/Department/10APPSERVER>.
<http://ex.com/Department/10APPSERVER> rdf:type ex:Department.
<http://ex.com/Department/10APPSERVER> ex:name "APPSERVER".

| ?s | ?p | ?o |
|---|---|---|
| http://ex.com/Person/7369 | rdf:type | ex:Employee |
| http://ex.com/Person/7369 | ex:name | "SMITH" |
| http://ex.com/Person/7369 | ex:name | "ADAM" |
| http://ex.com/Person/7369 | ex:fullname | "SMITH,ADAM" |
| http://ex.com/Person/7369 | ex:worksIn | http://ex.com/Department/10APPSERVER |
| http://ex.com/Department/10APPSERVER | rdf:type | ex:Department |
| http://ex.com/Department/10APPSERVER | ex:name | "APPServer" |

$[\![P_1]\!]_{[\![M]\!]_I}$

# QRP Problem Approach Step 4 ($P_2$)




```
:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=rdf:type.rdf:object=ex:Employee rdf:type rdf:Statement.
:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=rdf:type.rdf:object=ex:Employee rdf:Statement#rdf:subject ex.com/Person/7369.
:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=rdf:type.rdf:object=ex:Employee rdf:Statement#rdf:predicate rdf:type.
:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=rdf:type.rdf:object=ex:Employee rdf:Statement#rdf:object ex:Employee.

:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=ex:name.rdf:object=SMITH rdf:type rdf:Statement.
:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=ex:name.rdf:object=SMITH rdf:Statement#rdf:subject ex.com/Person/7369.
:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=ex:name.rdf:object=SMITH rdf:Statement#rdf:predicate ex:name.
:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=ex:name.rdf:object=SMITH rdf:Statement#rdf:object “SMITH”.

:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=ex:name.rdf:object=ADAM rdf:type rdf:Statement.
:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=ex:name.rdf:object=ADAM rdf:Statement#rdf:subject ex.com/Person/7369.
:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=ex:name.rdf:object=ADAM rdf:Statement#rdf:predicate ex:name.
:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=ex:name.rdf:object=ADAM rdf:Statement#rdf:object “ADAM”.

:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=ex:fullname.rdf:object=SMITH,ADAM rdf:type rdf:Statement.
:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=ex:fullname.rdf:object=SMITH,ADAM rdf:Statement#rdf:subject ex.com/Person/7369.
:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=ex:fullname.rdf:object=SMITH,ADAM rdf:Statement#rdf:predicate ex:fullname.
:rdf:Statement/rdf:subject=ex.com/Person/7369.rdf:predicate=ex:fullname.rdf:object=SMITH,ADAM rdf:Statement#rdf:object “SMITH,ADAM”.

:rdf:Statement/rdf:subject=ex.com/Person/7369.
```

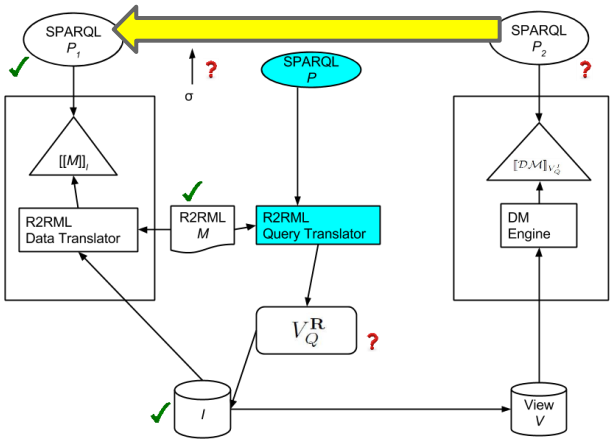
$[\![\mathcal{DM}]\!]_{V_Q^I}$

$P_2$ =
```
SELECT ?s ?p ?o WHERE {
  ?st a rdf:Statement .
  ?st rdf:Statement#rdf:subject ?s .
  ?st rdf:Statement#rdf:predicate ?p .
  ?st rdf:Statement#rdf:object ?o .}
```

| ?s | ?p | ?o |
|---|---|---|
| http://ex.com/Person/7369 | rdf:type | ex:Employee |
| http://ex.com/Person/7369 | ex:name | "SMITH" |
| http://ex.com/Person/7369 | ex:name | "ADAM" |
| http://ex.com/Person/7369 | ex:fullname | "SMITH,ADAM" |
| http://ex.com/Person/7369 | ex:worksIn | http://ex.com/Department/10APPSERVER |
| http://ex.com/Department/10APPSERVER | rdf:type | ex:Department |
| http://ex.com/Department/10APPSERVER | ex:name | "APPServer" |

# QRP Problem Solved

$\sigma = \{\}$




$$[\![P_1]\!]_{[\![M]\!]_I} = \sigma([\![P_2]\!]_{[\![\mathcal{DM}]\!]_{V_Q^I}})$$

| ?s | ?p | ?o |
|---|---|---|
| http://ex.com/Person/7369 | rdf:type | ex:Employee |
| http://ex.com/Person/7369 | ex:name | "SMITH" |
| http://ex.com/Person/7369 | ex:name | "ADAM" |
| http://ex.com/Person/7369 | ex:fullname | "SMITH,ADAM" |
| http://ex.com/Person/7369 | ex:worksIn | http://ex.com/Department/10APPSERVER |
| http://ex.com/Department/10APPSERVER | rdf:type | ex:Department |
| http://ex.com/Department/10APPSERVER | ex:name | "APPServer" |

# Summary

- R2RML <-> DM
  - DM -> R2RML (obvious)
  - R2RML -> DM ( ? )
    - $R2RML_{Lite}$
- We say they are “equivalent”, if
  - Information preservation property holds
  - Query result preservation property holds
- The consequence
  - R2RML engine (morph-RDB, D2RQ, ontop, etc) is not the only option for evaluating $R2RML_{Lite}$ mappings

# Future Work (FW) and Conclusions (C)

- FW1: Supporting more expressive R2RML fragment
- FW2: Use horizontal approach (see next slide)
- C1: DM + View + Substitution is as expressive as $R2RML_{Lite}$

- C2: Be very careful when choosing your internship topic!

# (FW2) Sneak Peek of Horizontal Approach

- Use mappings NF1
- Use self-join elimination
- Without reification
- Generate multiple tables, not a single triples table in the view
  - $P_{Department}$ = SELECT ?s ?ex_name ?ex_department WHERE {
    ?s rdf:type ex:Department .
    ?s ex:name  ?ex_name . }

  - $P_{Employee}$ = SELECT ?s ?ex_name ?ex_fullname ?ex_department WHERE {
    ?s rdf:type ex:Employee .
    ?s ex:name  ?ex_name .
    ?s ex:fullname ?ex_fullname .
    ?s ex:worksIn ?ex_worksIn. }