Data and Process Modelling

3. Object-Role Modeling - CSDP Step 4

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Uniqueness Constraints

CSDP Step 4

Add uniqueness constraints and check the arity of fact types.

1. Model uniqueness constraints (UCs): each base fact type must be assigned at least one UC.
   - UC: at most one fact of a certain type is allowed.
     (**`Each Person has at most one Weight`**).
   - Identify keys for the fact types.
2. Use UCs to evaluate the arity of fact types.
   - Uniqueness check to determine if a fact type is elementary or to be split.

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Remember: fact types like `Person has Weight` are snapshot fact types: instances belong to a single database state.

- Historical fact types can be modeled by explicitly referring to time: addition of a temporal role (`Person had Weight on Date`).

UC and Unary Fact Type

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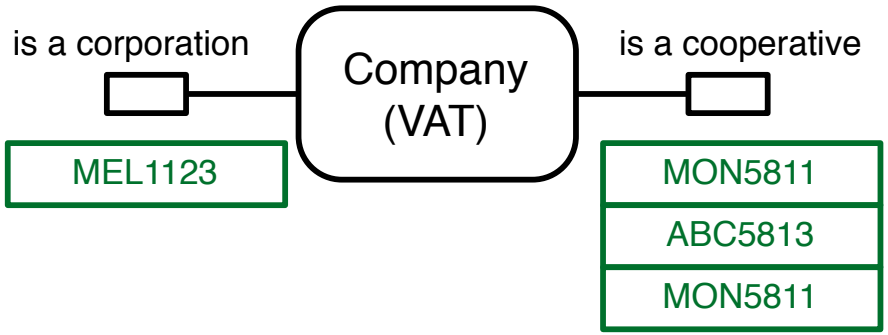

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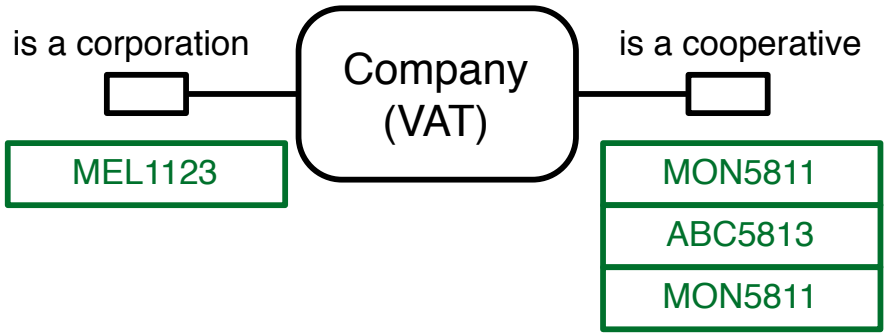
- Redundancy is sometimes accepted in the database, but *never* for elementary facts in the conceptual information base.



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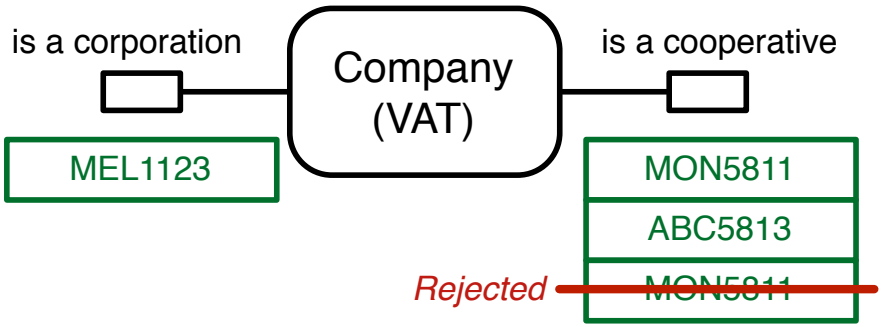
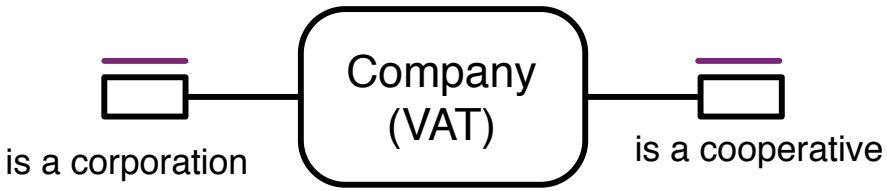


- No choice for unary fact types: every unary fact type is (implicitly) associated to an UC.
- UC represented as a bar above/below the single role: simple UC.



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1. Many-to-one (n:1): each `A` in relation `rel` with **at most one** `B`; each `B` in relation `rel` with **many (0+)** `A`s. (1 simple UC)
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3. One-to-one (1:1): each `A` in relation `rel` with **at most one** `B`, and **vice versa**. (2 simple UCs)
4. Many-to-many (n:m): each `A` in relation `rel` with **many (0+)** `B`, and **vice versa**. (1 composite UC)

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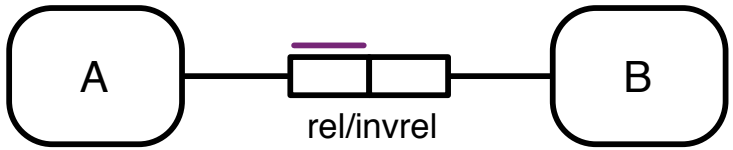
   - `rel` is a partial function of `A`.



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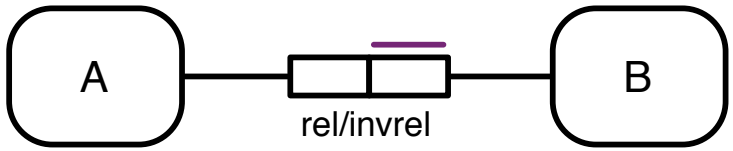
   - `invrel` is a partial function of `B`.



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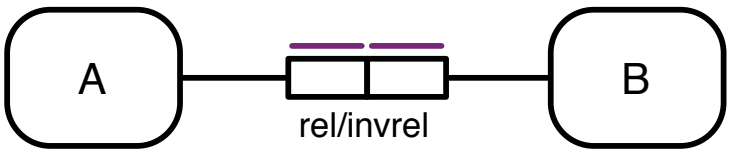
   - `invrel` is a the *inverse function* of `rel`: `invrel(rel(A)) = A`.
   - Used for reference types (abbreviated for the preferred reference mode).



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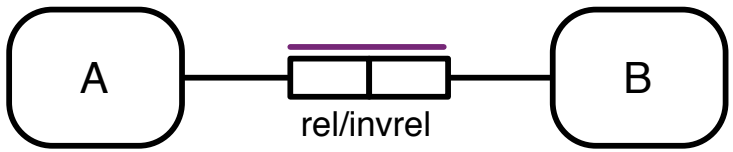
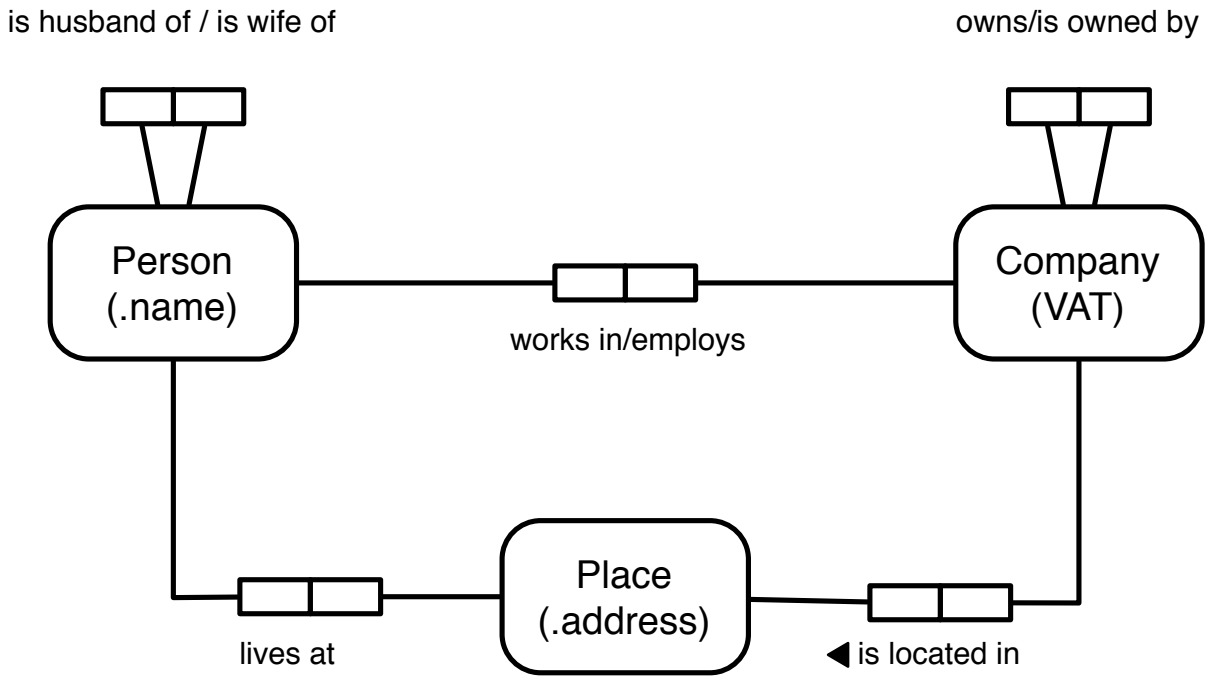
   - Spanning uniqueness constraint.
   - Always true (set semantics).
   - Most general: $(1.) \vee (2.) \vee (3.) \rightarrow (4.)$.
   - Verify with domain experts if bags are supported $\rightarrow$ ternary relation
     - ★ Temporization is a common case.



Constraints Elicitation



- Interaction with domain experts.
- Question each constraint in English, eliciting **counter-examples**.
  - Is it possible for a Person to live in more than one Place?
    Is it possible for a Company to be owned by more than one Company?
- Remember: a conceptual model is only an *approximation* of reality!
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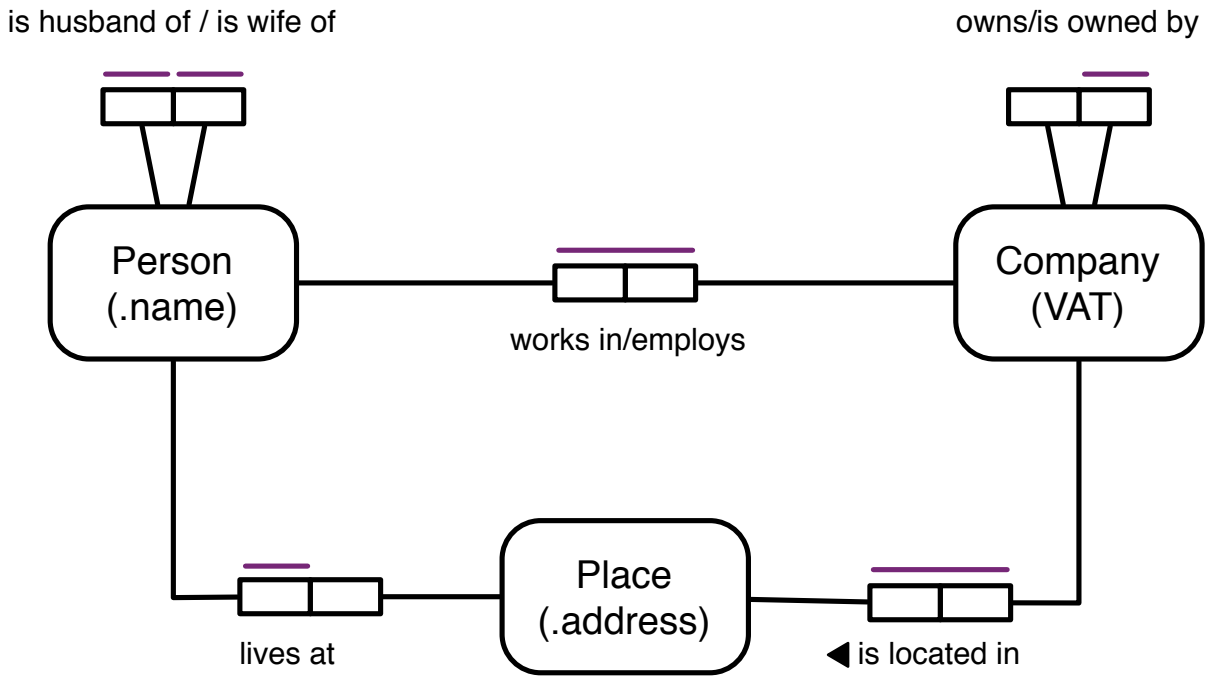

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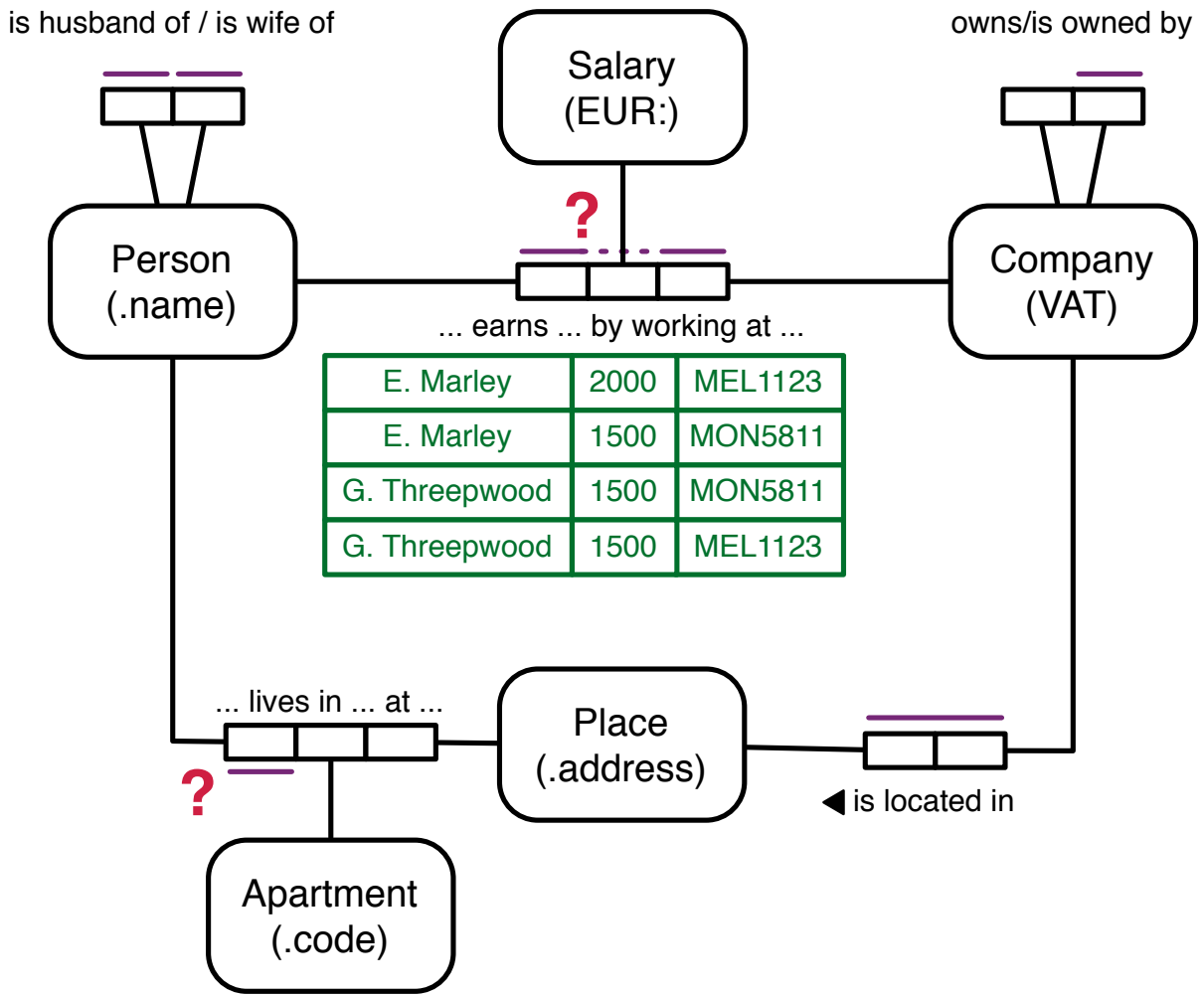
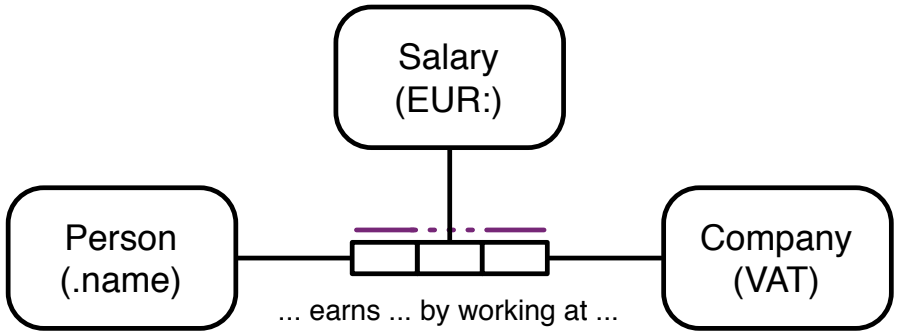


UC and Ternary Fact Types

- Deep case analysis using the available data (incomplete knowledge).
- Does a constraint make sense?
  - Very unlikely that Company+Salary univocally determines a Person.



E. Marley	2000	MEL1123
E. Marley	1500	MON5811
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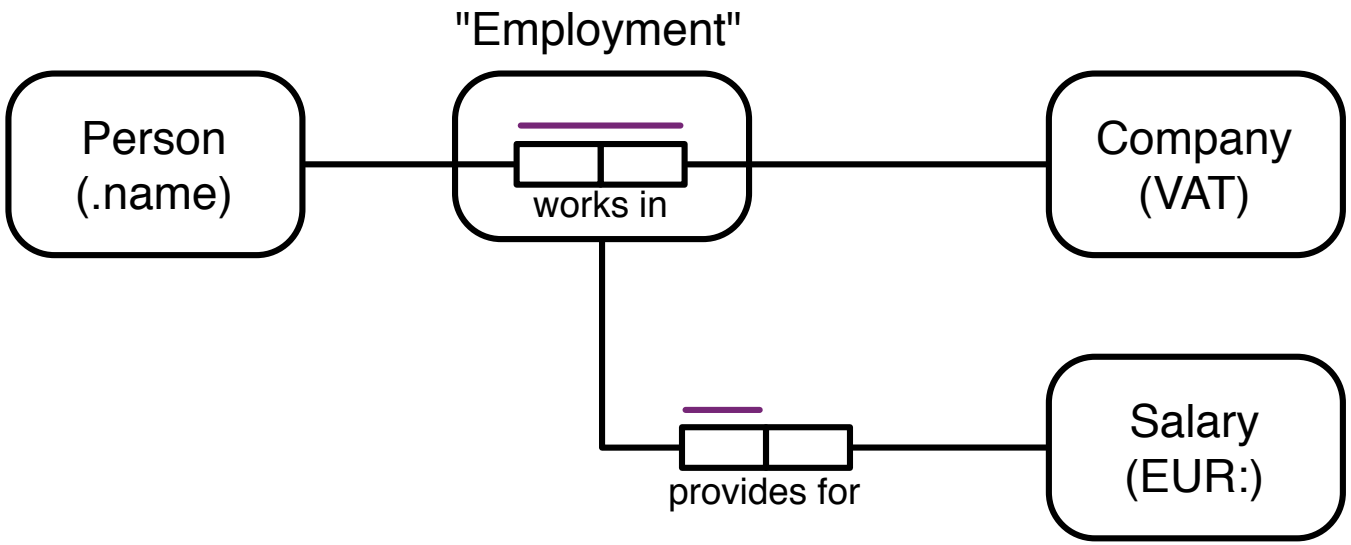
- Usage of divided constraint bar to write UCs over non-contiguous roles.

Ternary vs Objectified Association

Corresponding objectified diagram
(equivalent only if `provides for` is mandatory for `Employment`).



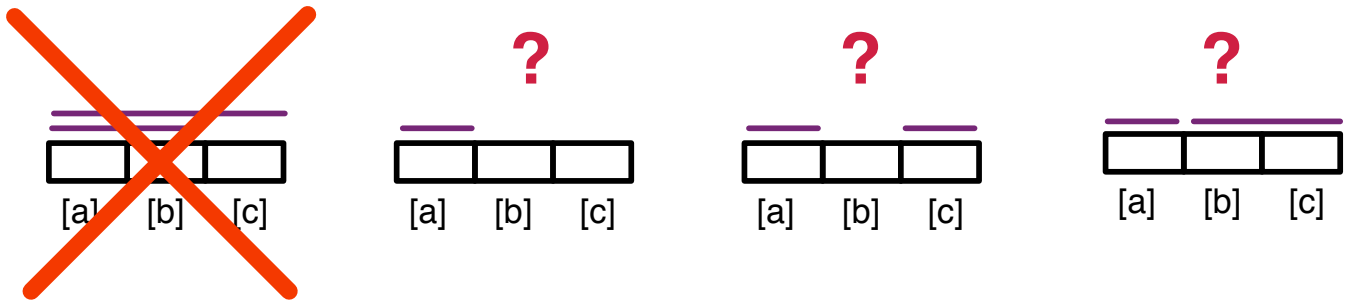
- Objectified associations must have a spanning UC (objectification introduces a reference to a combination of objects).
- If this is not true, refactor around the entity type(s) subject to the UC.
- Simple constraint on `provides for` predicate: each Employment (i.e., each pair (Person, Company)) is associated to at most one Salary.

UC and Ternary Fact Types: Possibilities

- Single UCs.

- Combined UCs.

- What about other possibilities?



UCs and Elementary Facts

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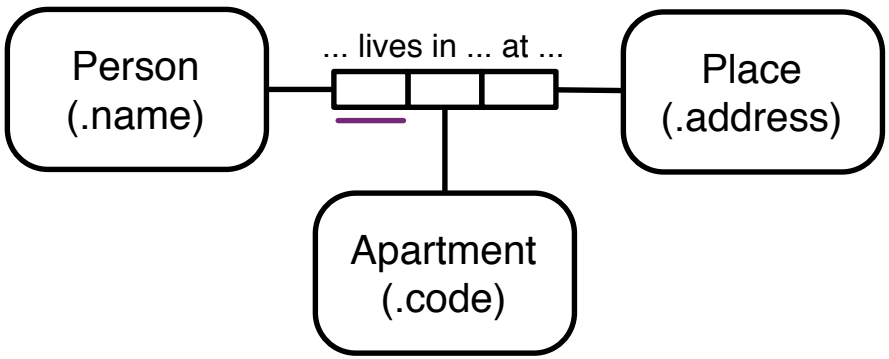

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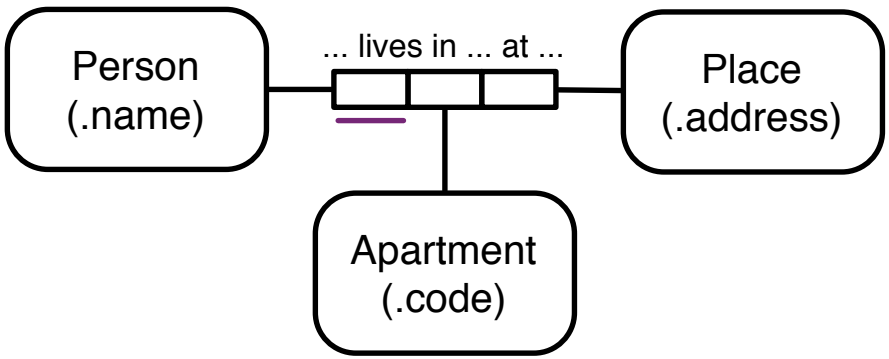

- Person acts as a pivot: determines both Apartment and Place.
- The UC *reveals* that the predicate is **non-elementary**.

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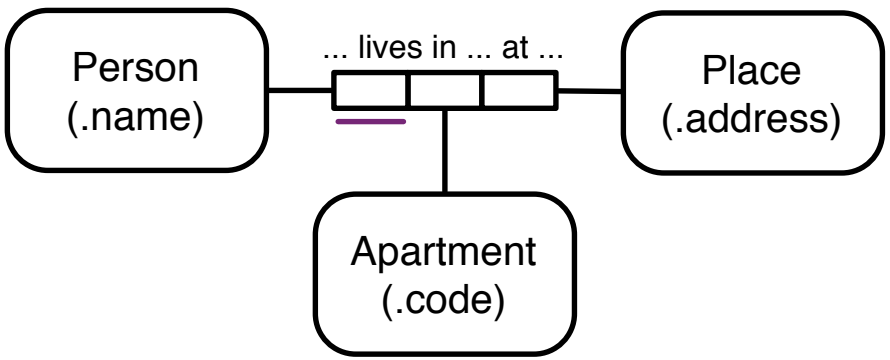

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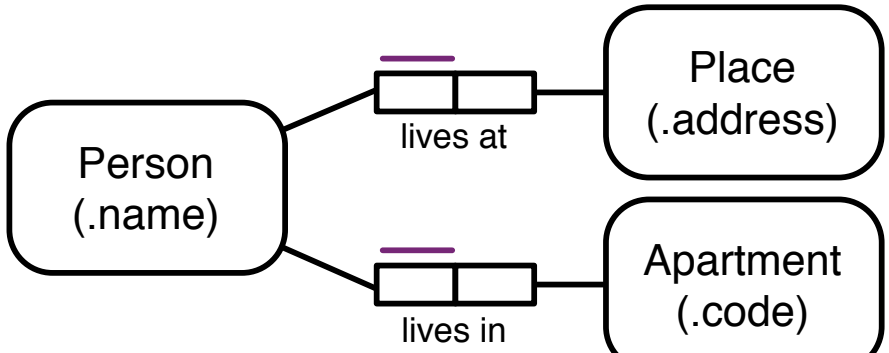

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Handling Non-Elementary Fact Types

Identification of non-elementary fact types in the model $\rightarrow$ decomposition.

- Key length check: UCs to identify predicates with too many roles.
  - *Sufficient* condition for splitting.
- Projection-join check: split and recombine information checking if there is information-loss.
  - Refine the sufficient condition for key length check.

Key Length Check

- Key: minimal combination of roles spanned by an UC.
  - Simple key: spans one role only.
- Predicates of wrong arity.
  - Too long: non-elementary fact type $\rightarrow$ to be split.
    - ★ Person lives in Apartment at Place
      $\rightarrow$ Person lives in Apartment; Person lives at Place.
  - Too short: information-loss $\rightarrow$ recombination.
    - ★ Lecturer teaches Course; Lecturer teaches at Faculty
      $\rightarrow$ Lecturer teaches Course at Faculty.
- Major issue: too long predicates.

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n-1 rule

Each n-ary fact type has a key length of at least n-1.

- Elementary fact type of arity n:
  1. has exactly one key of length n;
  2. has one or more keys of length n-1.
- Ternary fact type to be split if it has a simple key $\rightarrow$ split on the key.

Functional Dependencies

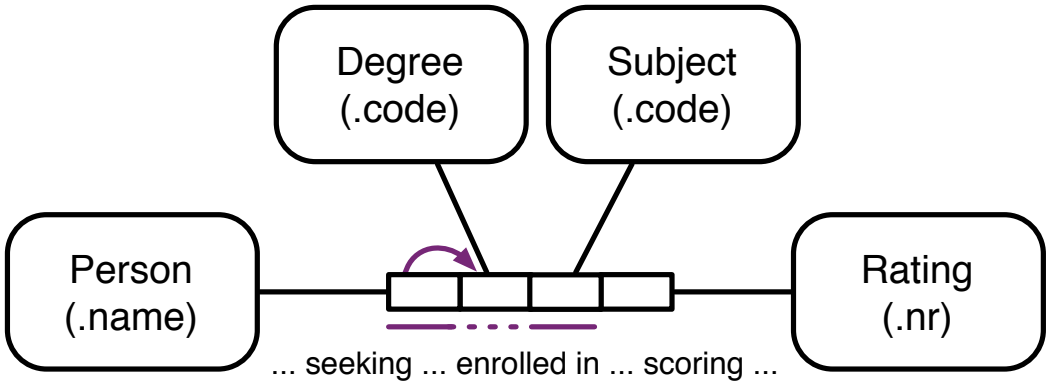
- Functional dependencies help in the decision of how to split.

Functional Dependency

Given a combination of columns X and a column Y in a fact table, Y functionally depends on X ($X \rightarrow Y$) if for each value of X there is at most one value of Y.

- Correct ORM schema: all FDs captured by UCs.
- $X \rightarrow Y$: there is a many-to-one relationship between X and Y.
- Suppose relation of arity n has key of size $< n - 1$.
  - Then there are at least two columns that functionally depend on key.
  - Split can be done by pairing each FD source with the corresponding target.
- Difficult to be exhaustively spotted: they are many and each one requires verbalization with the domain experts.
  - To be combined with human knowledge about the UoD.

FDs and Decomposition



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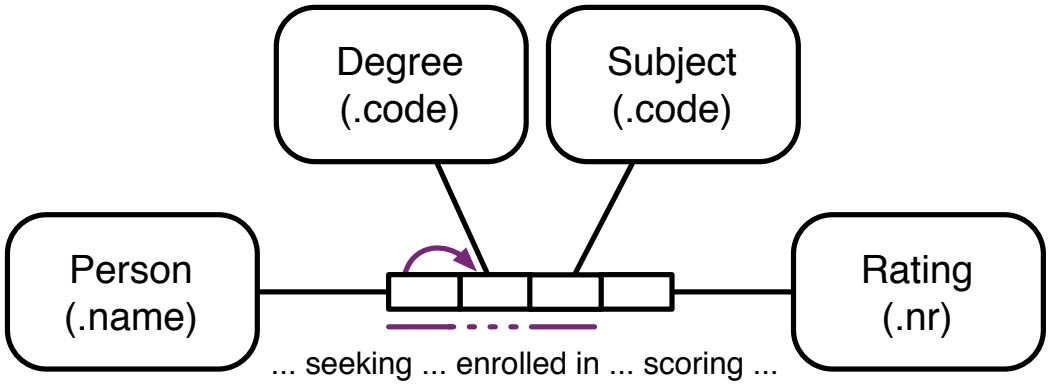
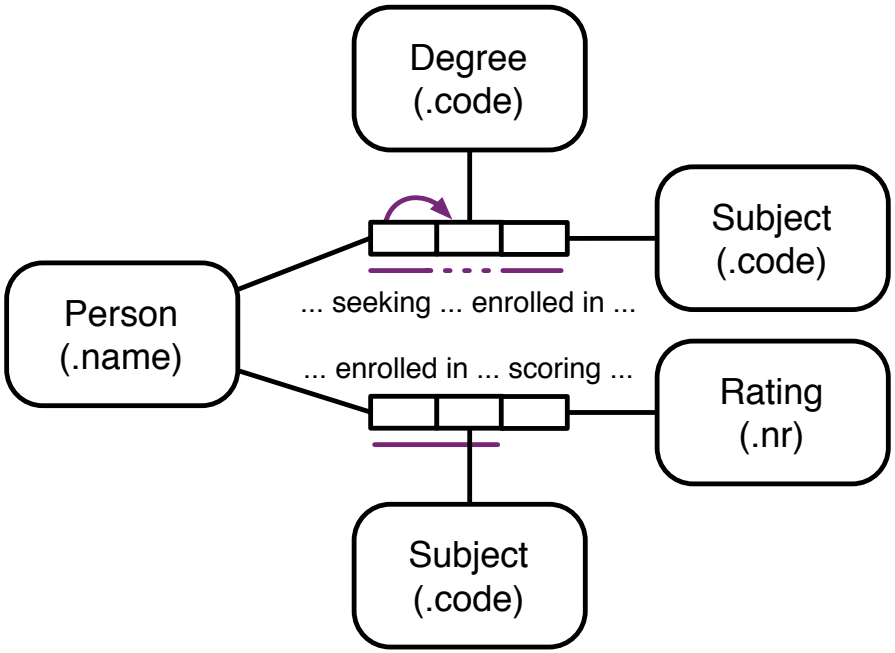


- FDs shown only in a "temporary" model.
- Is the model correct? Violation of the n-1 rule!

FDs and Decomposition

Decomposition using the UC as a pivot.



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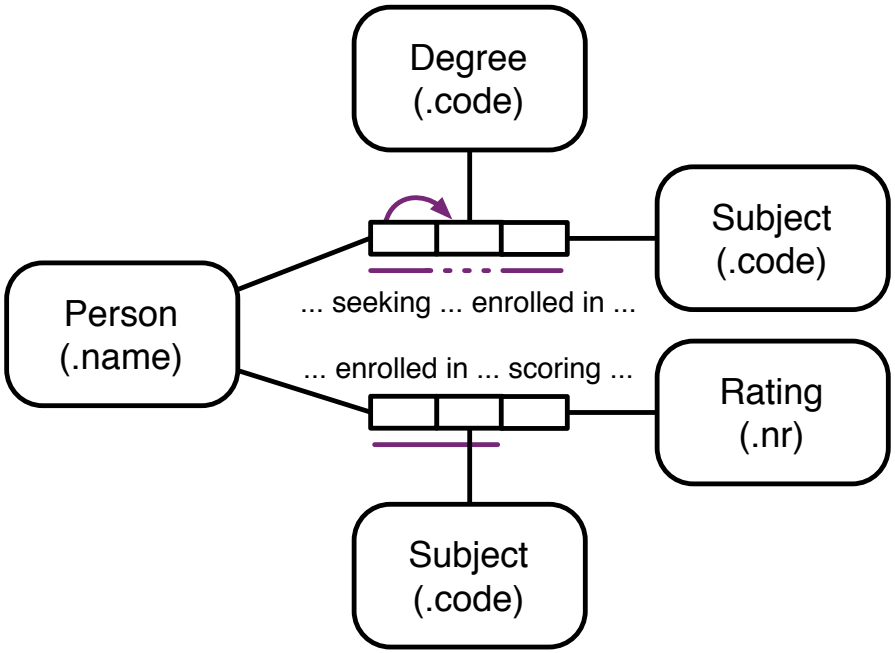
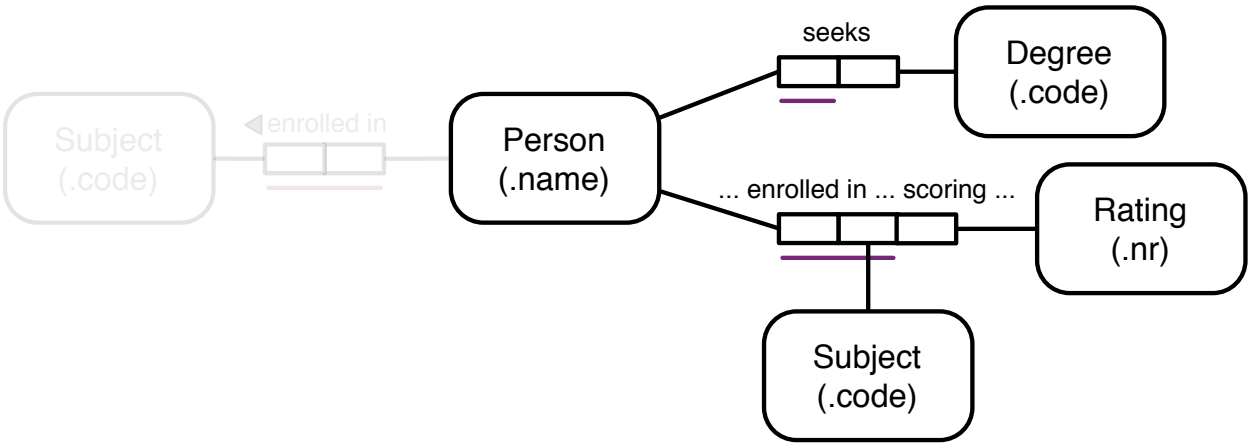


- Is the model correct? Relation is non-elementary due to the FD.
- The n-1 rule is a *sufficient* condition for splitting, but *not a necessary* one.

FDs and Decomposition

Decomposition using the source of FD as a pivot.



- Part of the decomposition is redundant $\rightarrow$ not included.

Conceptual Projection

Extraction of a portion of a fact table, obtained by maintaining only the desired columns.

- Set semantics: no repetitions inside the filtered table.
- Notation: $T[role_1,\ldots,role_n]$.
  - Corresponds to $\pi_{role_1,\ldots,role_n}(T)$ in relational algebra.
- Example:

T

EMPLOYEE	SALARY	COMPANY
E. Marley	2000	MEL1123
E. Marley	1500	MON5811
G. Threepwood	1500	MON5811
G. Threepwood	1500	MEL1123

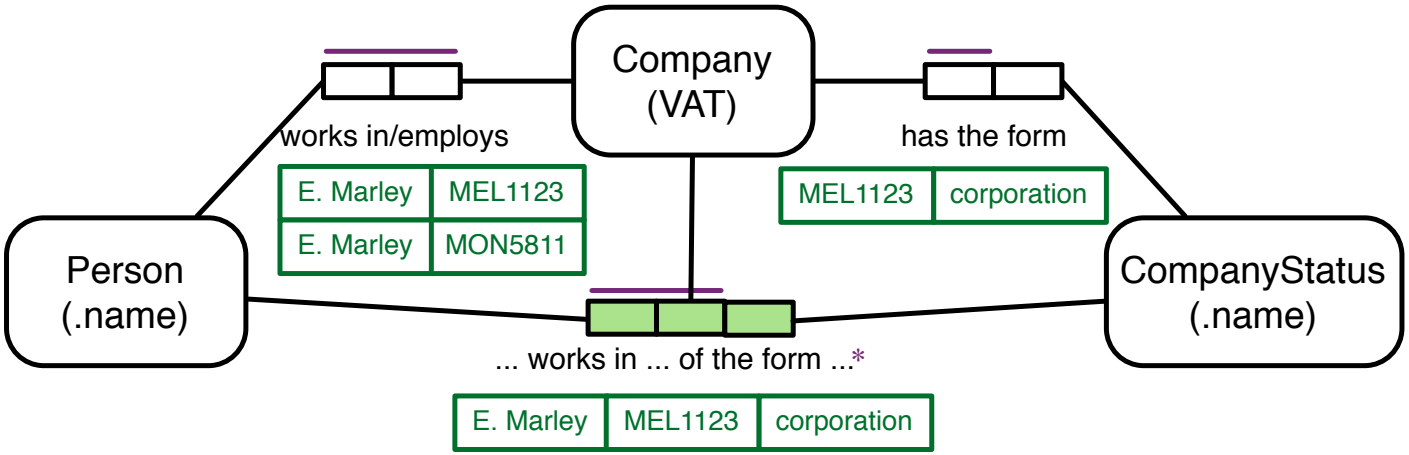
T[salary,company]

SALARY	COMPANY
2000	MEL1123
1500	MON5811
1500	MEL1123

Conceptual Join

Traversal of the conceptual schema from one fact type to another, passing through an object type.

Intuition for the navigation: when applying the conceptual join to concrete objects, the object of the join type is fixed.



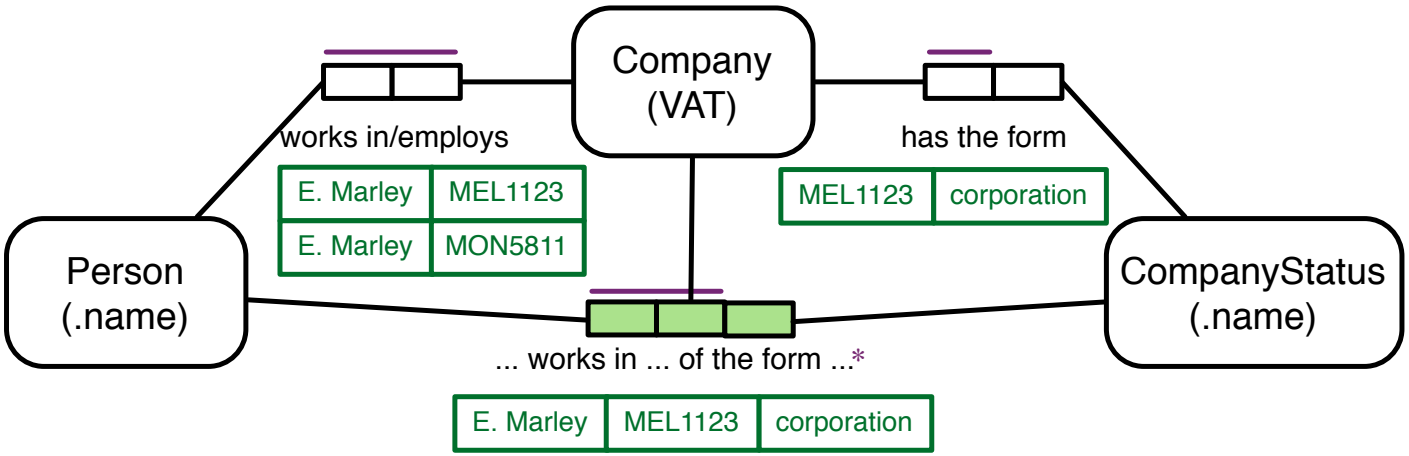

```
* define Person works in Company of the form CompanyStatus as
        Person works in Company that has the form CompanyStatus
```

The conceptual join gives raise to a *compound fact type*.

- obtained from the combination of different predicates by imposing **equivalence** among objects playing a certain role in them.

Types of Conceptual Join

- Conceptual inner join: join object must be the *same*.
- Left (right, full) outer join: also keep those facts for which the join object only appears in just the left (right, one of) fact table.
  - ? to denote the absence of a value (NULL).
  - Left outer join in the example: addition of `E. Marley MON5811 ?`.



* **define** Person works in Company of the form CompanyStatus **as**
Person works in Company **that** has the form CompanyStatus

Projection-Join Check

Tests whether a fact type is compound (hence splittable).

1. Provide a significant fact table for the fact type.
   - Must cover all the possible cases!
2. Split this table into two or more projections.
3. Recombine by conceptual (inner) join.
   - By construction no NULL entry.
4. The fact type is splittable in this way **if and only if** the result is the same as the original.

N.B.: usually having a significant fact table already supports the right choice.

Projection-Join Check

Suppose the fact table covers all possible cases.

- Is this fact type splittable?

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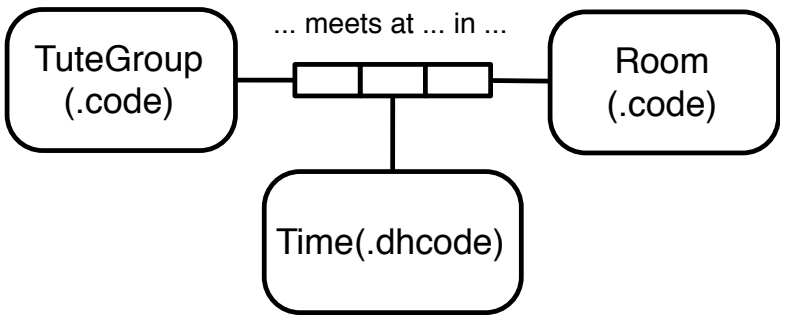
C	Mon. 3 p.m.	E-B18



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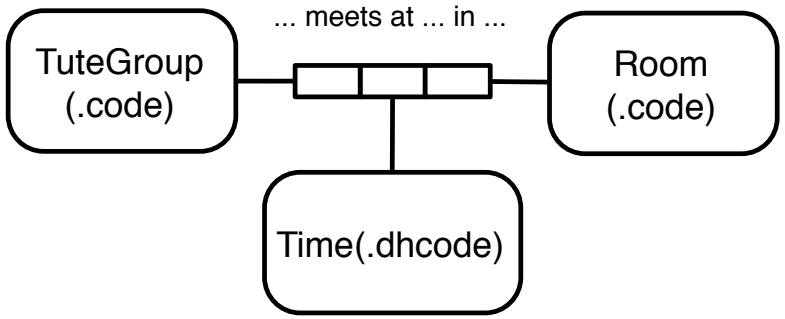

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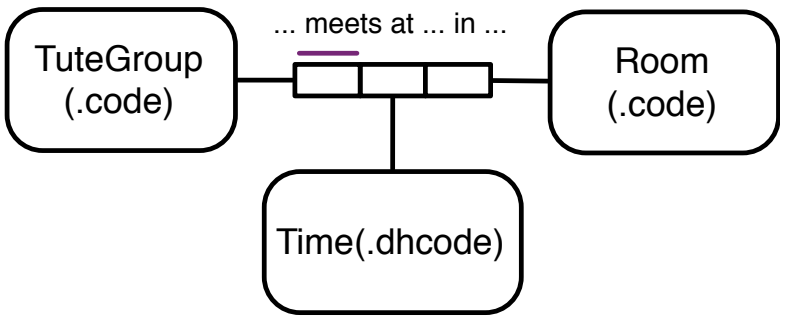

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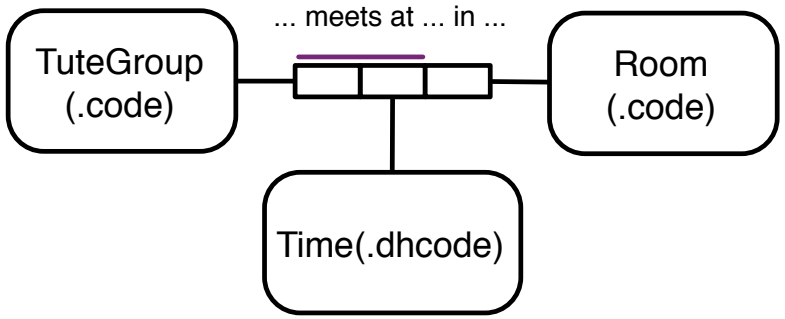
C	Mon. 3 p.m.	E-B18



External Uniqueness Constraints

Apply to roles from different predicates.

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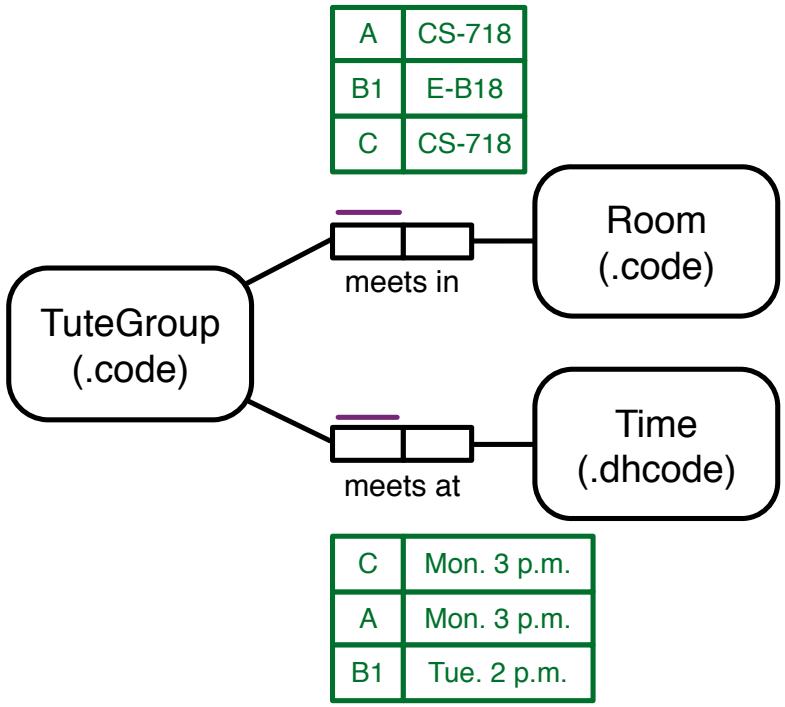

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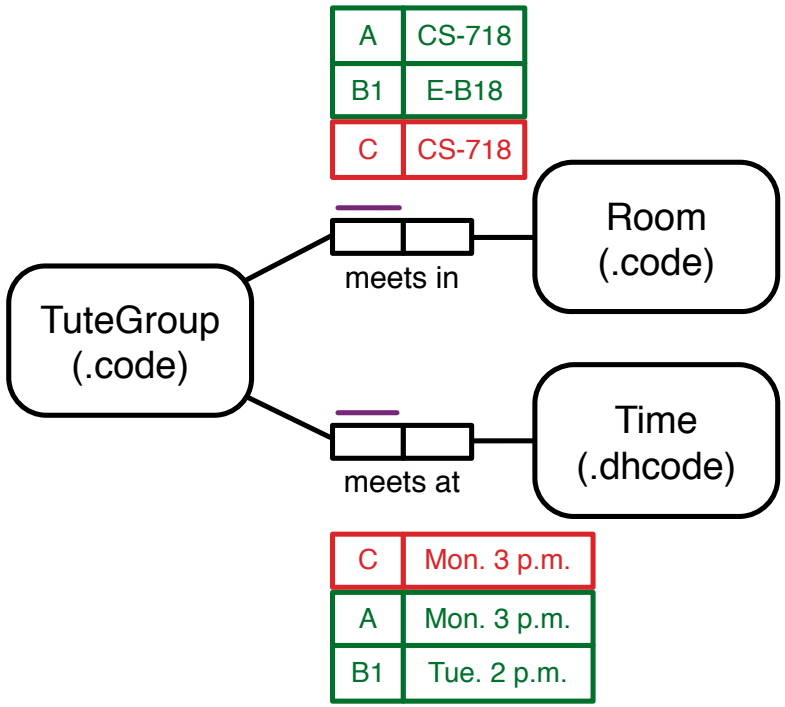

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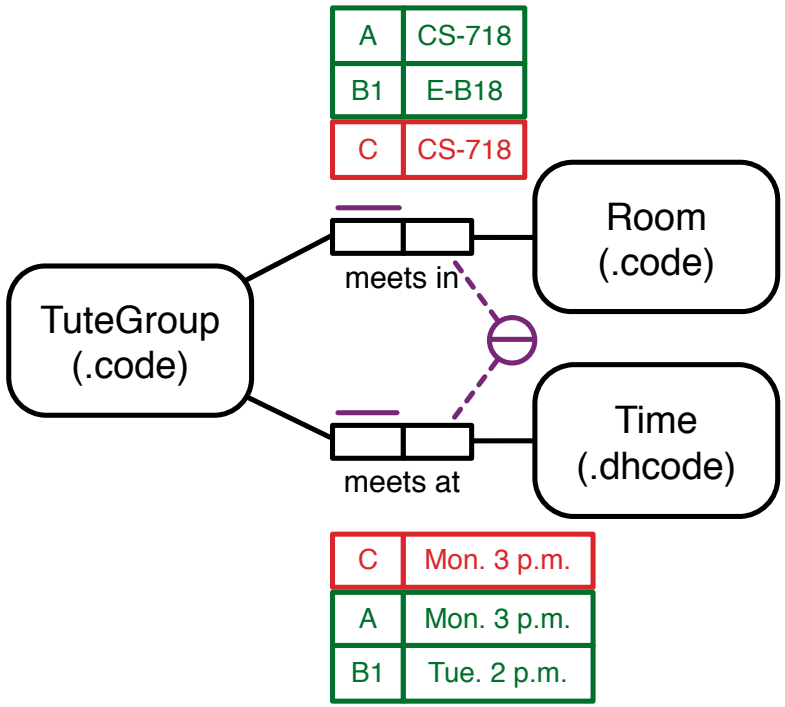

`Each combination of MeetingRoom and MeetingTime is paired with at most one TuteGroup`

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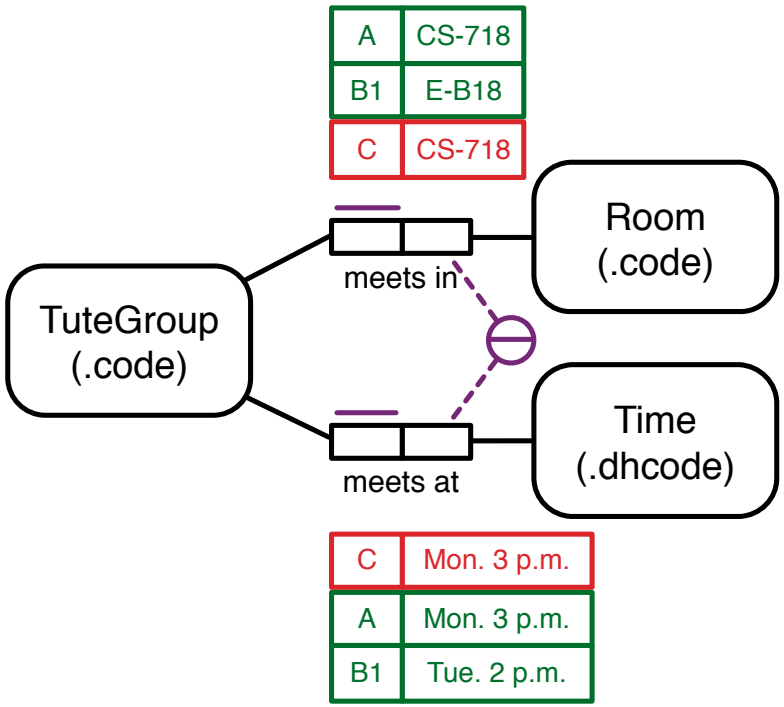
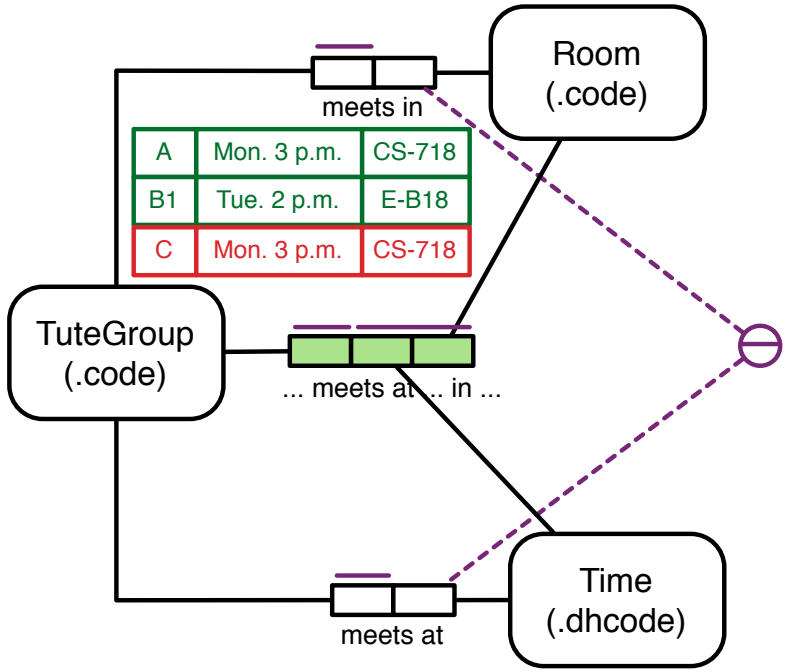
Apply to roles from different predicates.

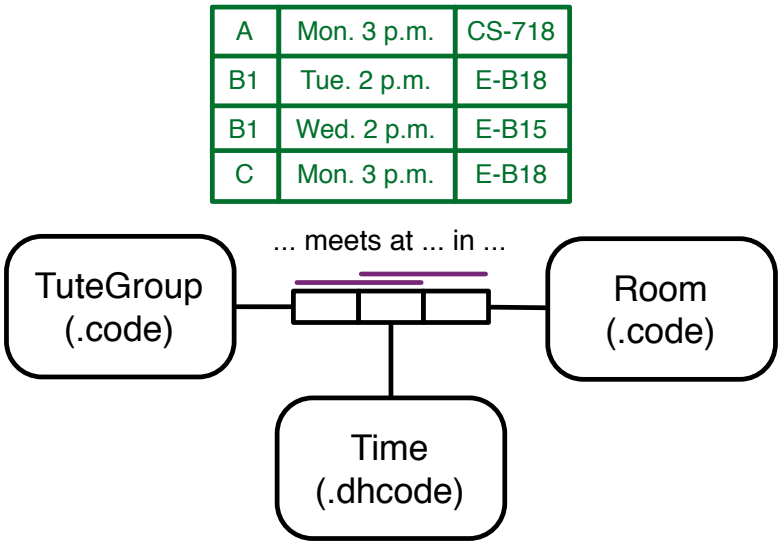


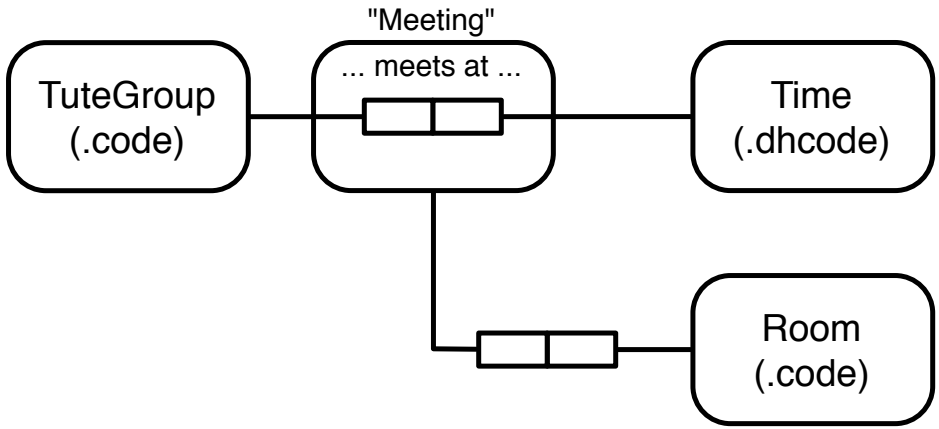


Each combination of MeetingRoom and MeetingTime is paired with at most one TuteGroup

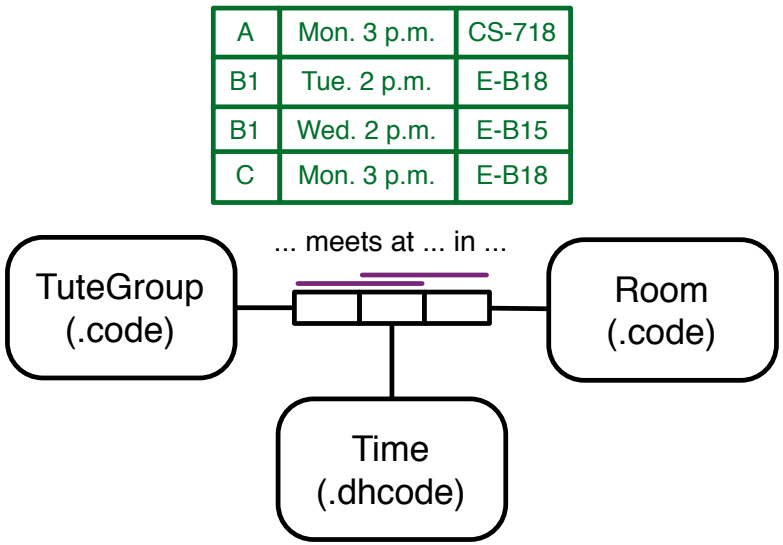
Each population of 'meets at' **join** 'meets in' has (Room,Time) unique

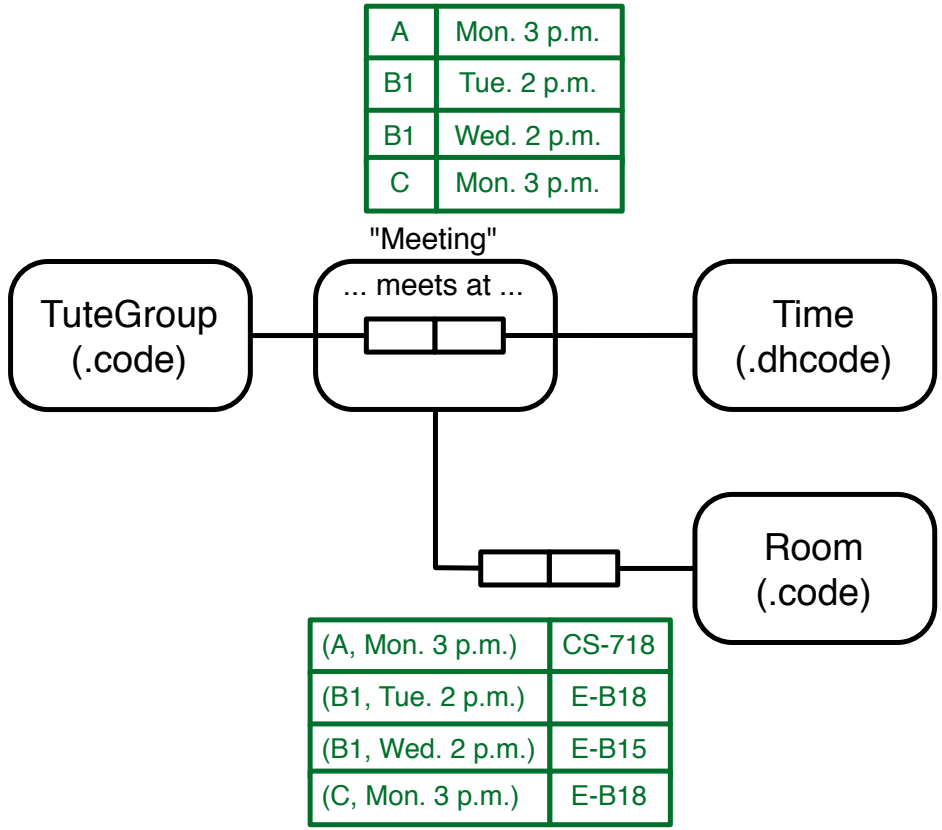
EUC and Objectification





EUC and Objectification





EUC and Objectification