The Relational Model

T. M. Murali

October 5, 2009

Course Outline

- Weeks 1–5, 13: Query/Manipulation Languages
  - The relational model
  - Relational Algebra
  - SQL
  - Data definition
  - Programming with SQL
- Weeks 6–8: Data Modelling
  - Entity-Relationship (E/R) approach
  - Good E/R design
  - Specifying Constraints
  - Converting E/R model to relational model.

Ideas $\longrightarrow$ E/R design $\longrightarrow$ Relational schema $\longrightarrow$ Relational DBMS

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Ideas $\longrightarrow$ E/R design $\longrightarrow$ Relational schema $\longrightarrow$ Relational DBMS

The Relational Model

- Built around a single concept for modelling data: the relation or table.
- Supports high-level programming language (SQL).
- Has an elegant mathematical design theory.
- Most current DBMS are relational.

The Relation

- A *relation* is a two-dimensional table:
  - Relation $\equiv$ table.
  - Attribute $\equiv$ column name.
  - Tuple $\equiv$ row (not the header row).
  - Database $\equiv$ collection of relations.

`CoursesTaken`

Student	*Course*	*Grade*
Hermione Grainger	Potions	A-
Draco Malfoy	Potions	B
Harry Potter	Potions	A
Ron Weasley	Potions	C

The Schema

CoursesTaken

Student	*Course*	*Grade*
Hermione Grainger	Potions	A-
Draco Malfoy	Potions	B
Harry Potter	Potions	A
Ron Weasley	Potions	C

- The *schema* of a relation is the name of the relation followed by a paranthetised list of attributes.

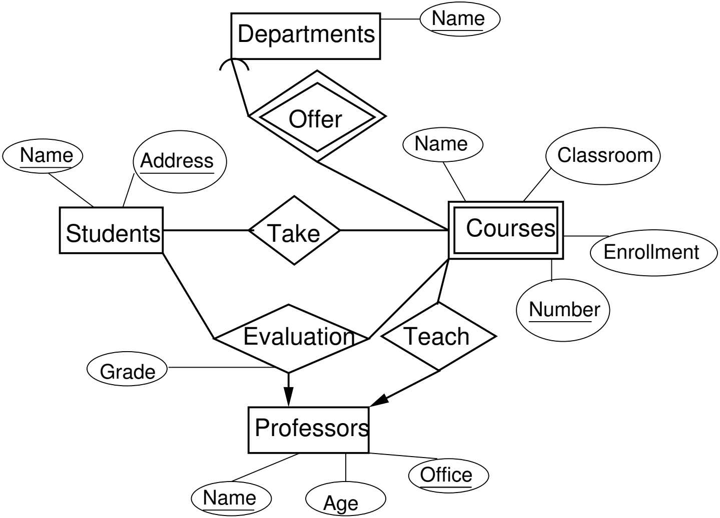
  `CoursesTaken(Student, Course, Grade)`

- A *design* in a relational model consists of a set of schemas.
  - Such a set of schemas is called a *relational database schema*.

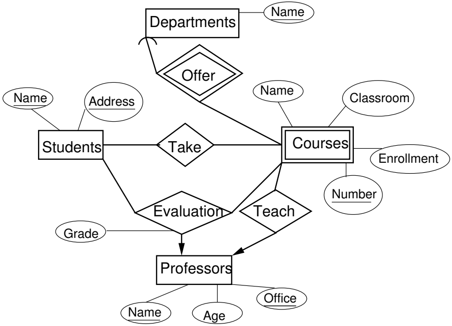
Converting E/R Diagrams to Relational Designs

- Entity set $\longrightarrow$ relation.
  - Attribute of an entity set $\longrightarrow$ attribute of a relation.
- Relationship $\longrightarrow$ relation whose attributes are
  - Attribute of the relationship itself.
  - Key attributes of the connected entity sets.
- Several special cases:
  - Weak entity sets.
  - Combining relations (especially for many-one relationships).
  - *Isa* relationships and subclasses.

Example for Conversion

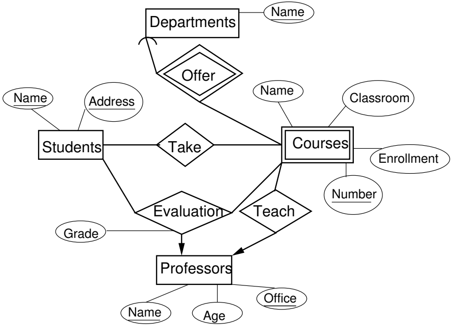


Schemas for Non-Weak Entity Sets



- For each entity set, create a relation with the same name and with the same set of attributes.

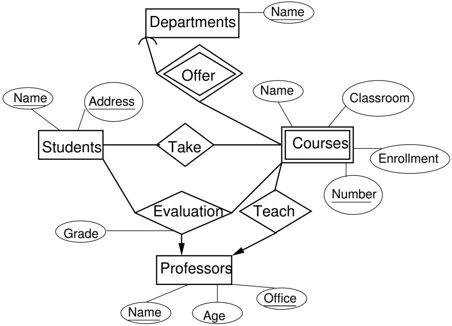
Schemas for Non-Weak Entity Sets



- For each entity set, create a relation with the same name and with the same set of attributes.

  `Students(Name, Address)`

Schemas for Non-Weak Entity Sets

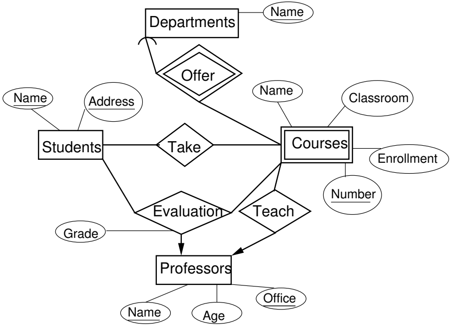


- For each entity set, create a relation with the same name and with the same set of attributes.

  `Students(Name, Address)`

  `Professors(Name, Office, Age)`

Schemas for Non-Weak Entity Sets



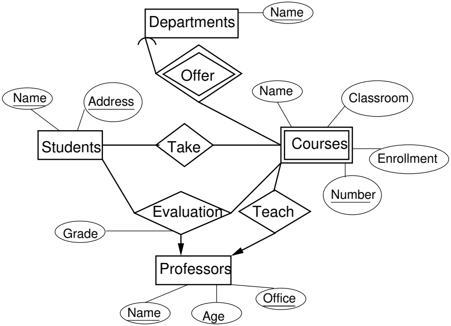
- For each entity set, create a relation with the same name and with the same set of attributes.

  `Students(Name, Address)`

  `Professors(Name, Office, Age)`

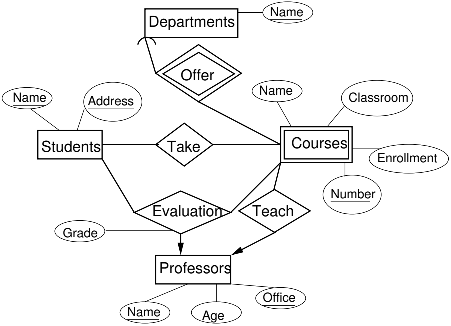
  `Departments(Name)`

Schemas for Weak Entity Sets



- For each weak entity set W, create a relation with the same name whose attributes are
  - Attributes of W and
  - Key attributes of the other entity sets that help form the key for W.

Schemas for Weak Entity Sets



- For each weak entity set W, create a relation with the same name whose attributes are
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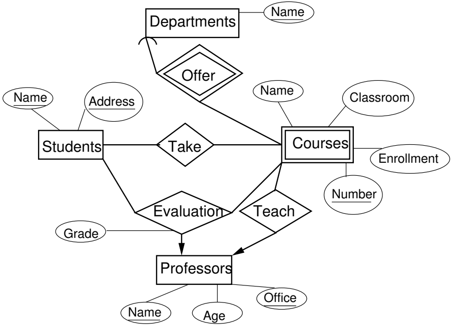
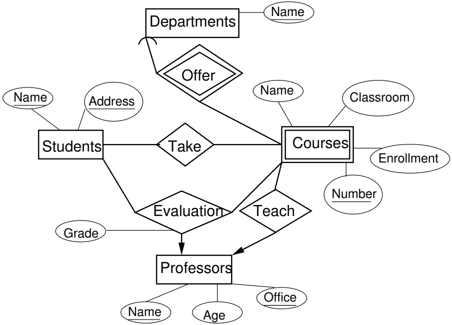
`Courses(Number, DepartmentName, CourseName, Classroom, Enrollment)`

Schemas for Non-Supporting Relationships (1)



- For each relationship, create a relation with the same name whose attributes are
  - Attributes of the relationship itself.
  - Key attributes of the connected entity sets (even if they are weak).

Schemas for Non-Supporting Relationships (2)



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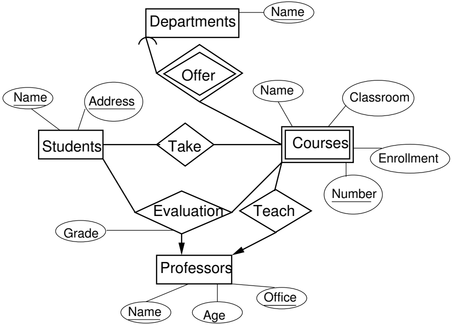
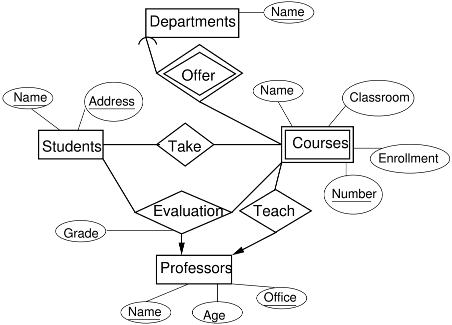


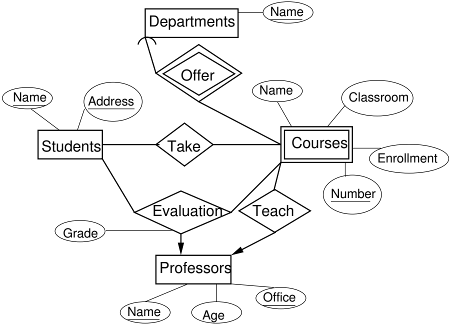
- `Take`

Schemas for Non-Supporting Relationships (2)



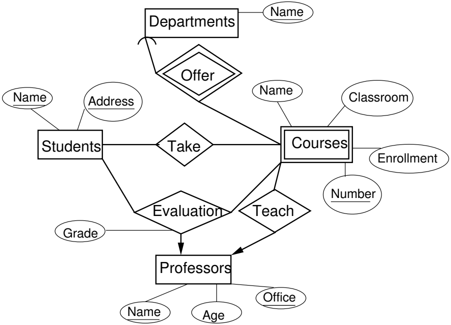
- `Take(StudentName, Address, Number, DepartmentName)`

Schemas for Non-Supporting Relationships (2)



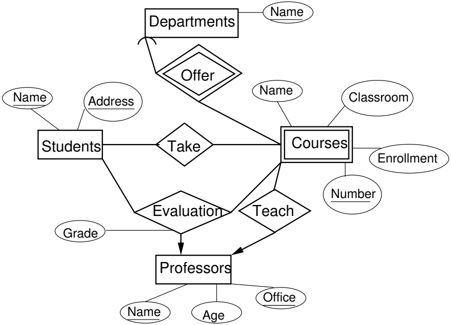
- `Take(StudentName, Address, Number, DepartmentName)`
- `Teach`

Schemas for Non-Supporting Relationships (2)



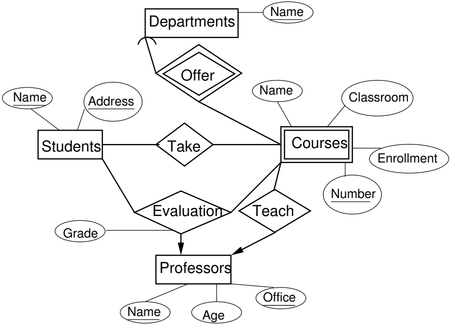
- `Take(StudentName, Address, Number, DepartmentName)`
- `Teach(ProfessorName, Office, Number, DepartmentName)`

Schemas for Non-Supporting Relationships (2)



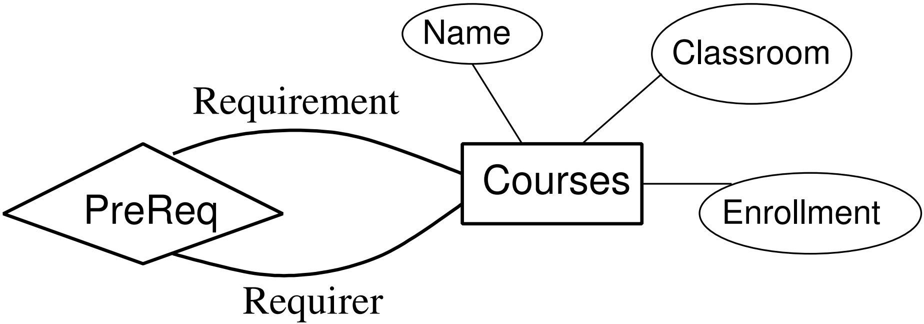
- `Take(StudentName, Address, Number, DepartmentName)`
- `Teach(ProfessorName, Office, Number, DepartmentName)`
- `Evaluation`

Schemas for Non-Supporting Relationships (2)



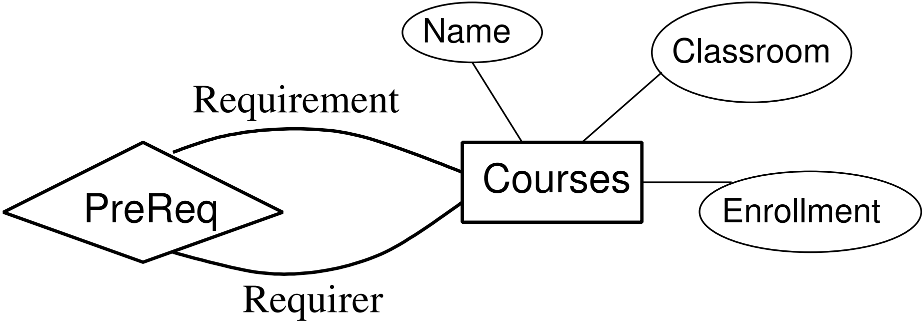
- `Take(StudentName, Address, Number, DepartmentName)`
- `Teach(ProfessorName, Office, Number, DepartmentName)`
- `Evaluation(StudentName, Address, ProfessorName, Office, Number, DepartmentName, Grade)`

Roles in Relationships



- If an entity set E appears $k > 1$ times in a relationship R (in different roles), the key attributes for E appear k times in the relation for R, appropriately renamed.

Roles in Relationships



- If an entity set E appears $k > 1$ times in a relationship R (in different roles), the key attributes for E appear k times in the relation for R, appropriately renamed.

  `PreReq(RequirerNumber, RequirerDeptName,`
  `RequirementNumber, RequirementDeptName)`

Combining Relations

- Consider many-one `Teach` relationship from `Courses` to `Professors`.
- Schemas are

```
Courses(Number, DepartmentName, CourseName, Classroom,
Enrollment)
Professors(Name, Office, Age)
Teach(Number, DepartmentName, ProfessorName, Office)
```

Combining Relations

- Consider many-one `Teach` relationship from `Courses` to `Professors`.
- Schemas are

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Courses(Number, DepartmentName, CourseName, Classroom,
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Teach(Number, DepartmentName, ProfessorName, Office)
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- The key for `Courses` uniquely determines all attributes of `Teach`.

Combining Relations

- Consider many-one `Teach` relationship from `Courses` to `Professors`.
- Schemas are

  `Courses(Number, DepartmentName, CourseName, Classroom, Enrollment)`

  `Professors(Name, Office, Age)`

  `Teach(Number, DepartmentName, ProfessorName, Office)`
- The key for `Courses` uniquely determines all attributes of `Teach`.
- We can combine the relations for `Courses` and `Teach` into a single relation whose attributes are
  - All the attributes for `Courses`,
  - Any attributes of `Teach`, and
  - The key attributes of `Professors`.

Rules for Combining Relations

- We can combine into one relation Q
  - The relation for an entity set E and
  - all many-to-one relationships $R_1, R_2, \ldots R_k$ from E to other entity sets $E_1, E_2, \ldots, E_k$, respectively.

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- The attributes of Q are
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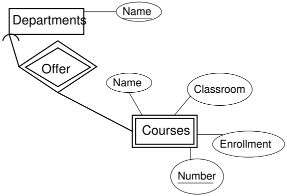
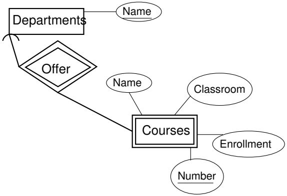
  - any attributes of $R_1, R_2, \ldots R_k$, and
  - the key attributes of $E_1, E_2, \ldots, E_k$.
- Can we combine E and R if R is a many-many relationship from E to F?

Supporting Relationships



- Schema for `Departments` is `Departments(Name)`.
- Schema for `Courses` is `Courses(Number, DepartmentName, CourseName, Classroom, Enrollment)`.

Supporting Relationships



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- What is the schema for `Offer`?

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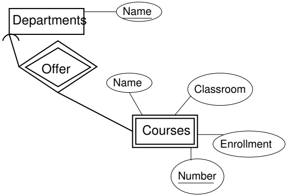

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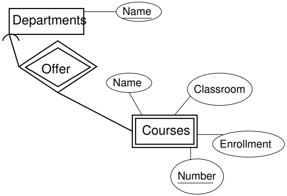
  - `Offer(Name, Number, DepartmentName)`.

Supporting Relationships



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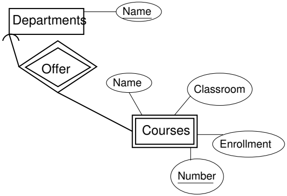
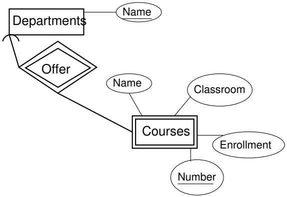
- Schema for `Courses` is `Courses(Number, DepartmentName, CourseName, Classroom, Enrollment)`.
- What is the schema for `Offer`?
  - `Offer(Name, Number, DepartmentName)`.
  - But `Name` and `DepartmentName` are identical, so the schema for `Offer` is `Offer(Number, DepartmentName)`.

Supporting Relationships



- Schema for `Departments` is `Departments(Name)`.
- Schema for `Courses` is `Courses(Number, DepartmentName, CourseName, Classroom, Enrollment)`.
- What is the schema for `Offer`?
  - `Offer(Name, Number, DepartmentName)`.
  - But `Name` and `DepartmentName` are identical, so the schema for `Offer` is `Offer(Number, DepartmentName)`.
  - The schema for `Offer` is a subset of the schema for the weak entity set, so we can dispense with the relation for `Offer`.

Summary of Weak Entity Sets



- If W is a weak entity set, the relation for W has a schema whose attributes are
  - all attributes of W,
  - all attributes of supporting relationships for W, and
  - for each supporting relationship for W to an entity set E, the key attributes of E.
- There is no relation for any supporting relationship for W.

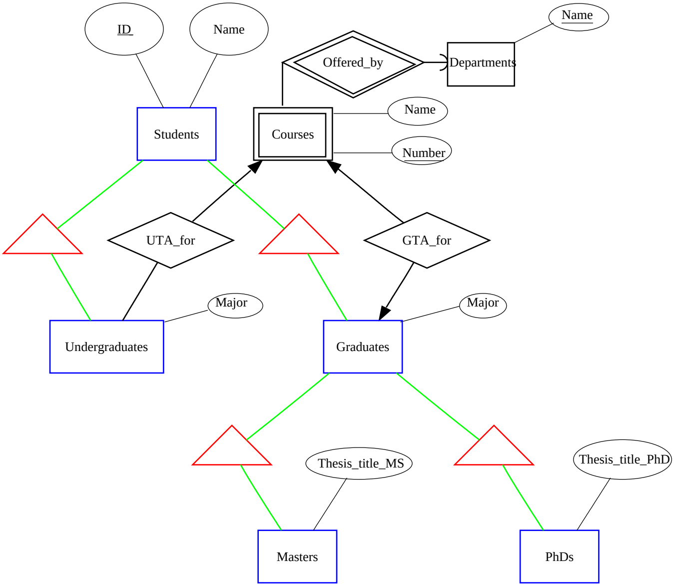
ISA to Relational

- Three approaches:
  1. E/R viewpoint
  2. Object-oriented viewpoint
  3. "Flatten" viewpoint

Rules Satisfied by an ISA Hierarchy

- The hierarchy has a root entity set.
- The root entity set has a key that identifies every entity represented by the hierarchy.
- A particular entity can have components that belong to entity sets of any subtree of the hierarchy, as long as that subtree includes the root.

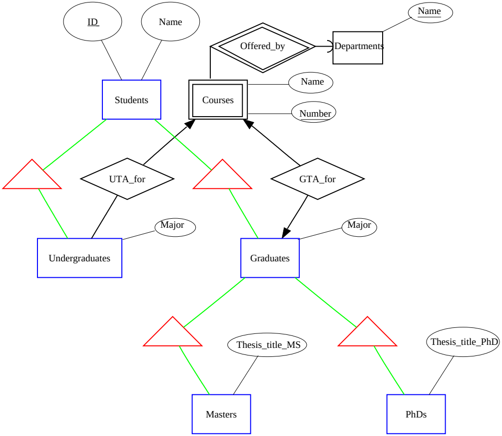
Example ISA hierarchy



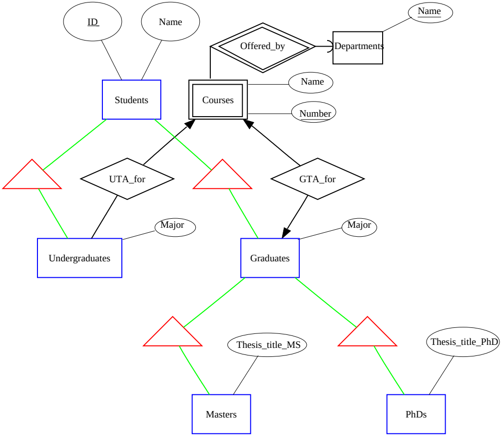
ISA to Relational Method I: E/R Approach

- Create a relation for each entity set.
- The attributes of the relation for a non-root entity set E are
  - the attributes forming the key (obtained from the root) and
  - any attributes of E itself.
- An entity with components in multiple entity sets has tuples in all the relations corresponding to these entity sets.
- Do not create a relation for any *isa* relationship.
- Create a relation for every other relationship.

ISA to Relational Method I: E/R Approach Example

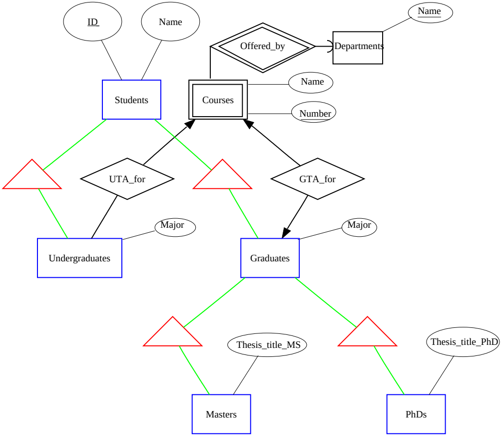


ISA to Relational Method I: E/R Approach Example



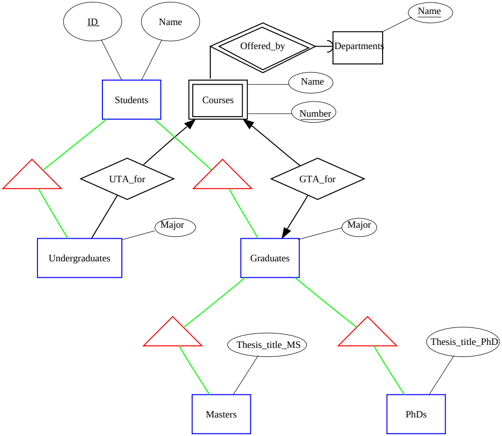
Students

ISA to Relational Method I: E/R Approach Example



Students(ID, Name)

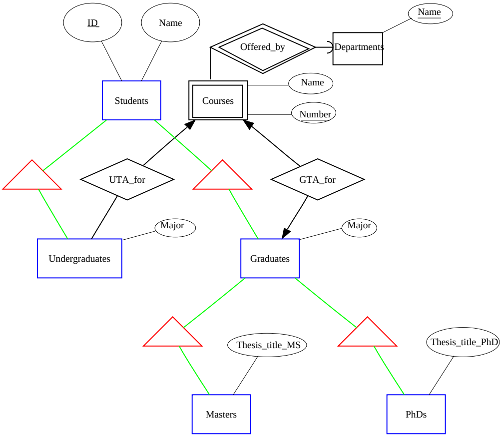
ISA to Relational Method I: E/R Approach Example



`Students(ID, Name)`

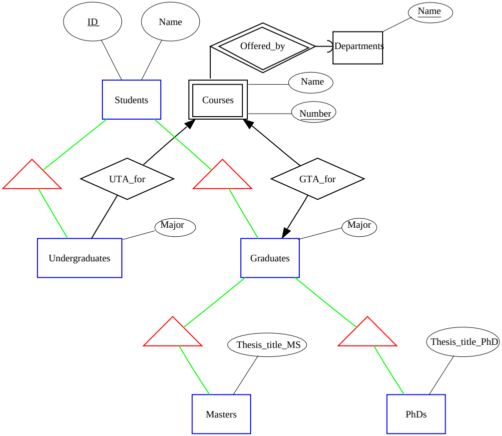
`Undergraduates`

ISA to Relational Method I: E/R Approach Example



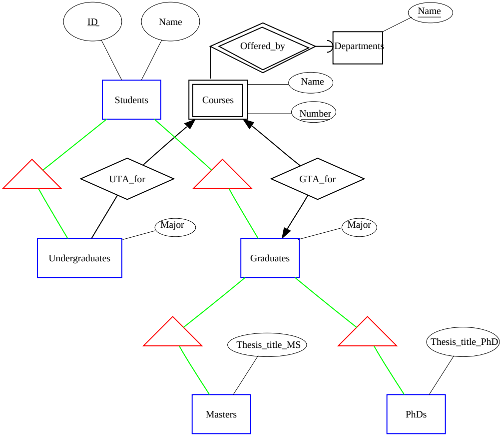

```
Students(ID, Name)
Undergraduates(ID, Major)
```

ISA to Relational Method I: E/R Approach Example



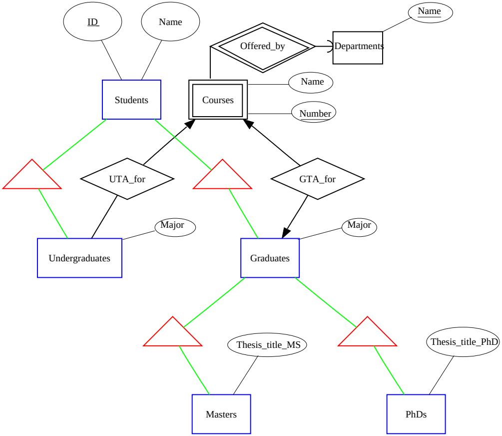

```
Students(ID, Name)
Undergraduates(ID, Major)
Graduates
```

ISA to Relational Method I: E/R Approach Example



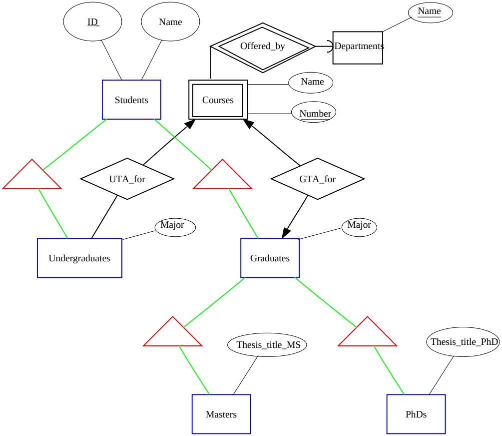

```
Students(ID, Name)
Undergraduates(ID, Major)
Graduates(ID, Major)
```

ISA to Relational Method I: E/R Approach Example



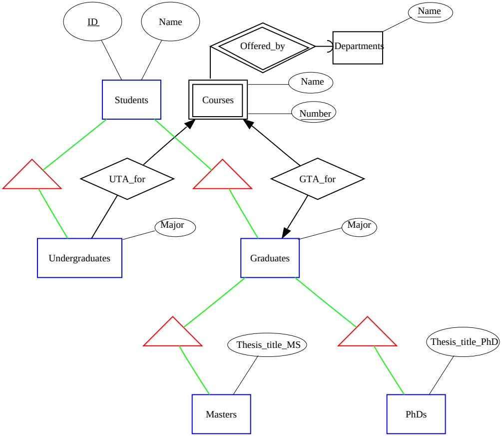

```
Students(ID, Name)
Undergraduates(ID, Major)
Graduates(ID, Major)
Masters
```

ISA to Relational Method I: E/R Approach Example



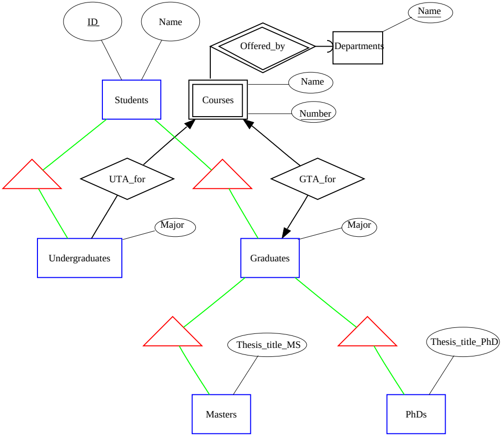

```
Students(ID, Name)
Undergraduates(ID, Major)
Graduates(ID, Major)
Masters(ID, Thesis_title_MS)
```

ISA to Relational Method I: E/R Approach Example



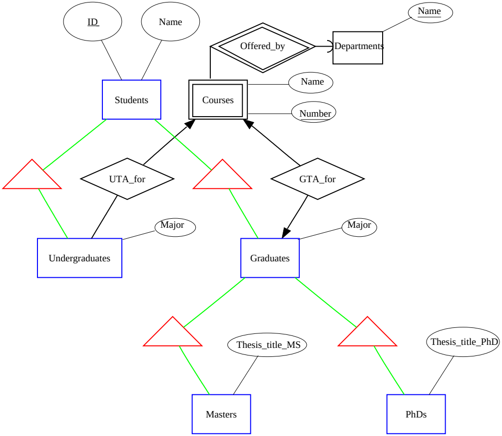

```
Students(ID, Name)
Undergraduates(ID, Major)
Graduates(ID, Major)
Masters(ID, Thesis_title_MS)
PhDs
```

ISA to Relational Method I: E/R Approach Example



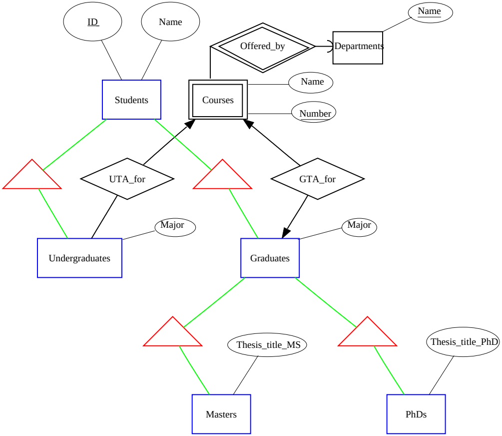

```
Students(ID, Name)
Undergraduates(ID, Major)
Graduates(ID, Major)
Masters(ID, Thesis_title_MS)
PhDs(ID, Thesis_title_PhD)
```

ISA to Relational Method I: E/R Approach Example




```
Students(ID, Name)
Undergraduates(ID, Major)
Graduates(ID, Major)
Masters(ID, Thesis_title_MS)
PhDs(ID, Thesis_title_PhD)
UTA_for
```

ISA to Relational Method I: E/R Approach Example



Students(ID, Name)

Undergraduates(ID, Major)

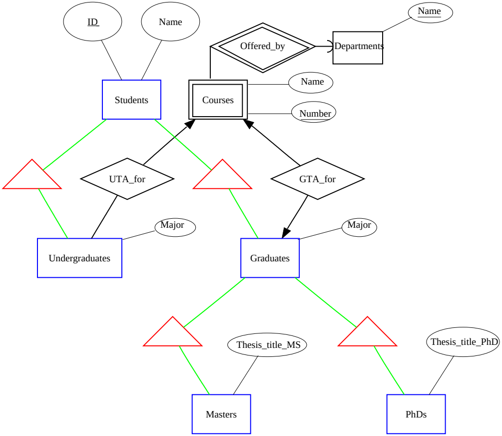
Graduates(ID, Major)

Masters(ID, Thesis_title_MS)

PhDs(ID, Thesis_title_PhD)

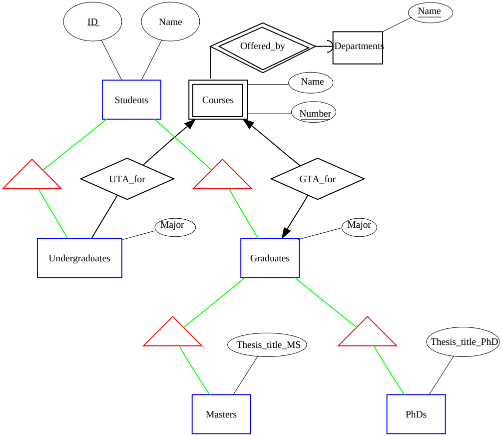
UTA_for(ID, CourseNumber, DepartmentName)

ISA to Relational Method I: E/R Approach Example




```
Students(ID, Name)
Undergraduates(ID, Major)
Graduates(ID, Major)
Masters(ID, Thesis_title_MS)
PhDs(ID, Thesis_title_PhD)
UTA_for(ID, CourseNumber,
DepartmentName)
GTA_for
```

ISA to Relational Method I: E/R Approach Example



Students(ID, Name)

Undergraduates(ID, Major)

Graduates(ID, Major)

Masters(ID, Thesis_title_MS)

PhDs(ID, Thesis_title_PhD)

UTA_for(ID, CourseNumber, DepartmentName)

GTA_for(ID, CourseNumber, DepartmentName)

ISA to Relational Method II: "Flatten" Approach

- Create a *single* relation for the entire hierarchy.
- Attributes are
  - the key attributes of the root and
  - the attributes of each entity set in the hierarchy.
- Handle relationships as before.

ISA to Relational Method II: "Flatten" Approach

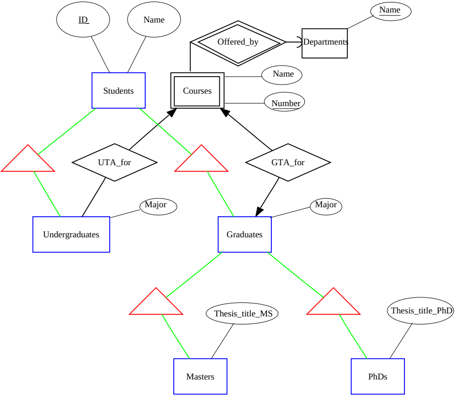
- Create a *single* relation for the entire hierarchy.
- Attributes are
  - the key attributes of the root and
  - the attributes of each entity set in the hierarchy.
- Handle relationships as before.

  `Students(ID, Name, UGMajor, GMajor, Thesis_title_MS, Thesis_title_PhD).`

ISA to Relational Method III: Object-Oriented Approach (1)

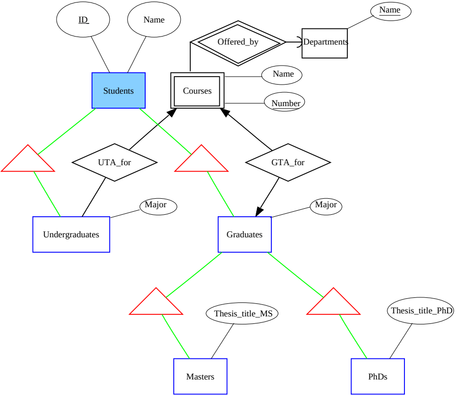
- Treat entities as objects belonging to a single class.
- "Class" $\equiv$ subtree of the hierarchy that includes the root.
- Enumerate all subtrees of the hierarchy that contain the root.
- For each such subtree,
  - Create a relation that represents entities that have components in exactly that subtree.
  - The schema for this relation has all the attributes of all the entity sets in that subtree.
- Schema of the relation for a relationship has key attributes of the connected entity sets.

ISA to Relational Method III: Object-Oriented Approach (2)



- Subtrees are

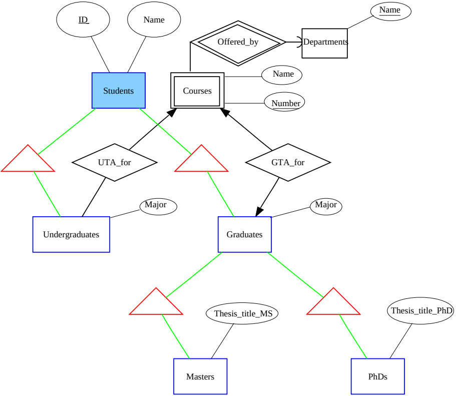
ISA to Relational Method III: Object-Oriented Approach (2)



- Subtrees are

    `Students`

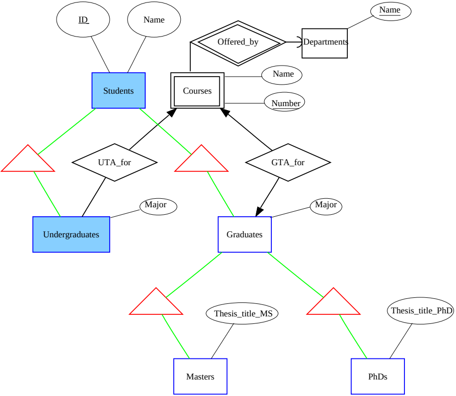
ISA to Relational Method III: Object-Oriented Approach (2)



- Subtrees are

  `Students(ID)`

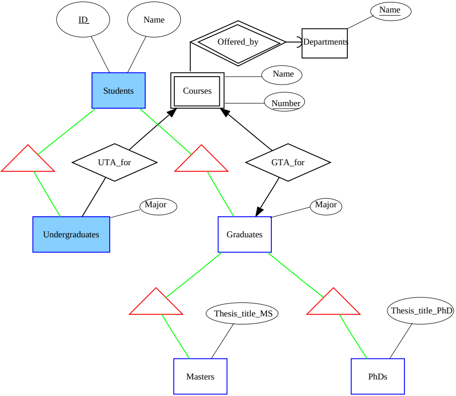
ISA to Relational Method III: Object-Oriented Approach (2)



- Subtrees are

  `Students(ID)`
  `StudentsUGs`

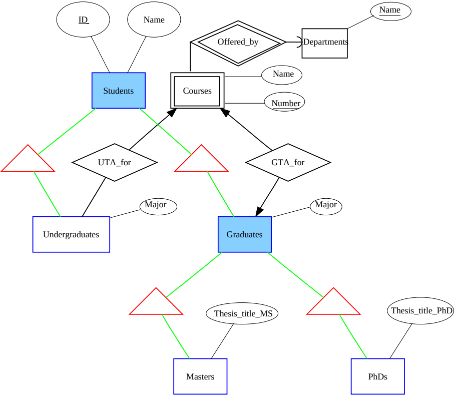
ISA to Relational Method III: Object-Oriented Approach (2)



- Subtrees are

  `Students(ID)`
  `StudentsUGs(ID, Major)`

ISA to Relational Method III: Object-Oriented Approach (2)



- Subtrees are

  `Students(ID)`
  `StudentsUGs(ID, Major)`
  `StudentsGs`

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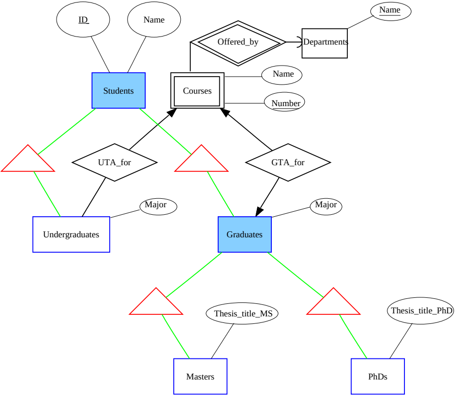
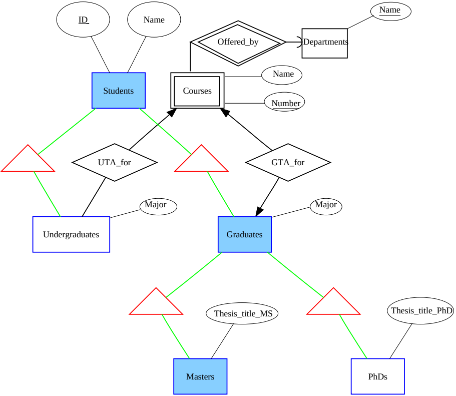


- Subtrees are

  `Students(ID)`
  `StudentsUGs(ID, Major)`
  `StudentsGs(ID, Major)`

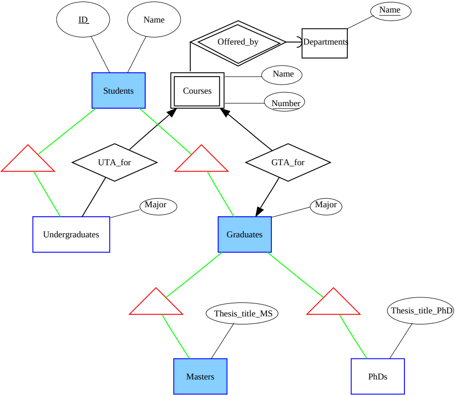
ISA to Relational Method III: Object-Oriented Approach (2)



- Subtrees are

```
Students(ID)
StudentsUGs(ID, Major)
StudentsGs(ID, Major)
StudentsGsMasters
```

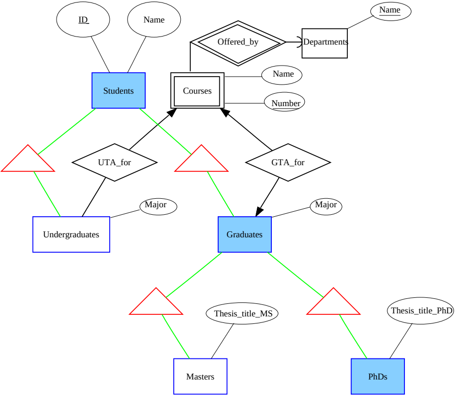
ISA to Relational Method III: Object-Oriented Approach (2)



- Subtrees are

```
Students(ID)
StudentsUGs(ID, Major)
StudentsGs(ID, Major)
StudentsGsMasters(ID, Major,
Thesis_title_MS)
```

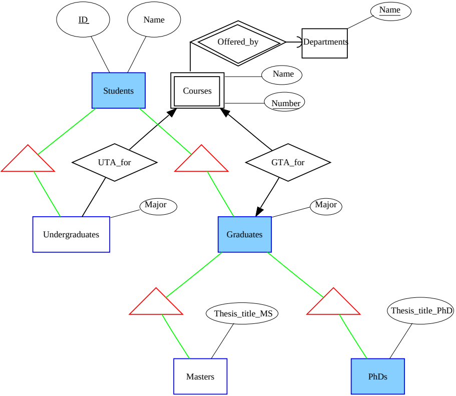
ISA to Relational Method III: Object-Oriented Approach (2)



- Subtrees are

  ```
  Students(ID)
  StudentsUGs(ID, Major)
  StudentsGs(ID, Major)
  StudentsGsMasters(ID, Major,
  Thesis_title_MS)
  StudentsGsPhDs
  ```

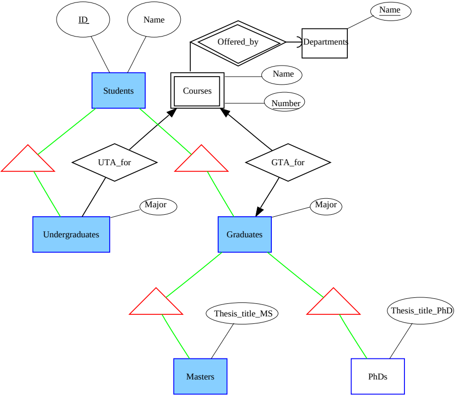
ISA to Relational Method III: Object-Oriented Approach (2)



- Subtrees are

```
Students(ID)
StudentsUGs(ID, Major)
StudentsGs(ID, Major)
StudentsGsMasters(ID, Major,
Thesis_title_MS)
StudentsGsPhDs(ID, Major,
Thesis_title_PhD)
```

ISA to Relational Method III: Object-Oriented Approach (2)



- Subtrees are

```
Students(ID)
StudentsUGs(ID, Major)
StudentsGs(ID, Major)
StudentsGsMasters(ID, Major,
Thesis_title_MS)
StudentsGsPhDs(ID, Major,
Thesis_title_PhD)
StudentsUGsGsMasters
```

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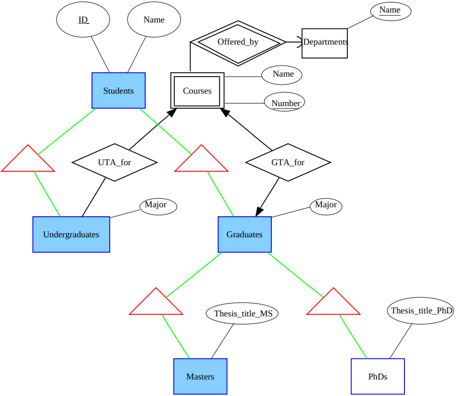
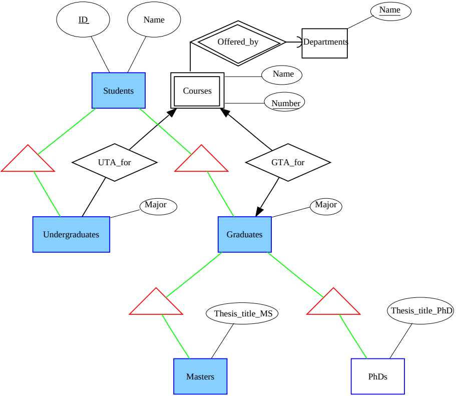


- Subtrees are

  Students(ID)
  StudentsUGs(ID, Major)
  StudentsGs(ID, Major)
  StudentsGsMasters(ID, Major, Thesis_title_MS)
  StudentsGsPhDs(ID, Major, Thesis_title_PhD)
  StudentsUGsGsMasters(ID, UGMinor, GradMinor, Thesis_title_MS)

ISA to Relational Method III: Object-Oriented Approach (2)



- Subtrees are

  Students(ID)
  StudentsUGs(ID, Major)
  StudentsGs(ID, Major)
  StudentsGsMasters(ID, Major, Thesis_title_MS)
  StudentsGsPhDs(ID, Major, Thesis_title_PhD)
  StudentsUGsGsMasters(ID, UGMinor, GradMinor, Thesis_title_MS)
  - What other subtrees exist?

ISA to Relational: Comparison of the Three Approaches

- Answering queries
  - It is expensive to answer queries involving several relations.
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  - E/R: Several tuples per entity, but only key attributes repeated.