Lecture 9 – Data Model Implementation

Advanced Data Management

UniTS – DMG

Data model implementation

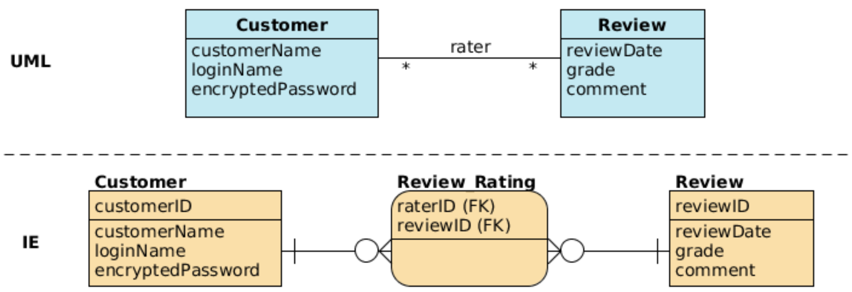
- Once we have designed a data model in UML, we need to convert the diagrams into machine readable formats
  - To perform additional validations to the data model, e.g. homogeneity, common naming rules
  - To be able to persist objects and relations which are compliant with the designed data model
- The implementation depends on the underlying technology:
  - For relational databases: database schema
  - For document oriented databases: the XML Schema Language (XSD) or the JSON Schema (JavaScript Object Notation)
- Document based systems can also be built on top of relational databases
- In this lecture we will focus on the relational database schema.

Object-relational impedance mismatch

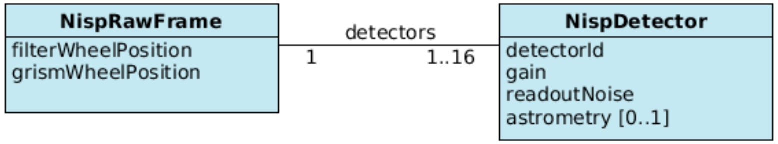
- A set of conceptual and technical difficulties that are often encountered when a relational database management system is been served by an application program written in an object oriented language
- We have already discussed some solutions when comparing the UML model with the IE model in the previous lecture
- Additional difficulties:
  - Hierarchical structure:
    - In UML, we can define complex hierarchical structures. A class can “aggregate” instances of other classes. The relational model only “accepts” atomic types for the entity attributes and relations
    - In the relational model, children point to their parent, while in the hierarchical model parents point to their children
  - Inheritance:
    - Not directly supported by the relational model. Several mappings can be implemented to keep the inheritance information
  - Class normalization vs data normalization

Examples

- Many-to-many associations, when mapped to a relational schema, require an additional table, i.e. an additional relation



- In the relational schema we cannot define an upper limit on the multiplicity



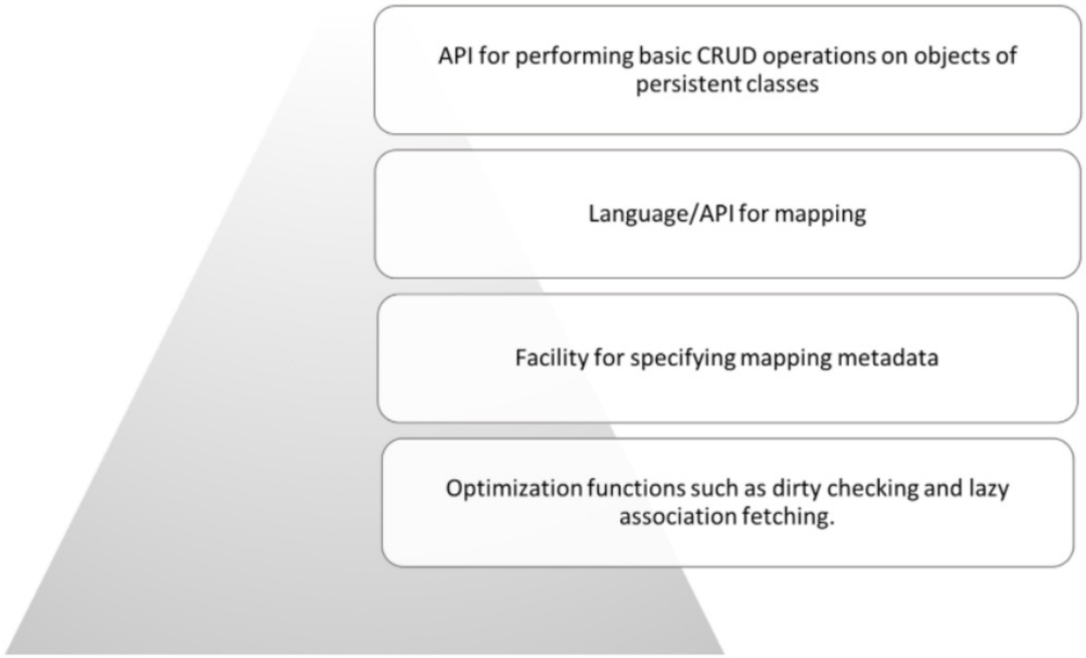
- Abstract classes have multiple mapping options, each one with some limitations

Specialization and generalization

- We consider here only the single inheritance
- To convert each specialization with m subclasses $\{S_1, S_2, \dots, S_m\}$ and superclass C, where the attributes of C are $\{k, a_1, a_2, \dots, a_n\}$ and k is the primary key, into a relation schema, the options are:
  - **Multiple relations - superclass and subclasses**. Create a relation L for C with attributes Attrs(L) = $\{k, a_1, \dots, a_n\}$ and PK(L) = k. Create a relation L_i for each subclass S_i, with attributes Attrs(L_i) = $\{k\} \cup \{$attributes of $S_i\}$ and PK(L_i) = k.
  - **Multiple relations – subclass only**. Create a relation L_i for each subclass S_i, with the attributes Attrs(L_i) = $\{$attributes of $S_i\} \cup \{k, a_1, \dots, a_n\}$ and PK(L_i) = k.
  - **Single relation with one type attribute**. Create a single relation schema L with attributes Attrs(L) = $\{k, a_1, \dots, a_n\} \cup \{$attributes of $S_1\} \cup \dots \cup \{$attributes of $S_m\} \cup \{t\}$ and PK(L) = k. The attribute t is called type (or discriminating) attribute whose value indicates the subclass to which each tuple belongs
  - **Single relation multiple type attributes**. As above, but instead of a single type attribute t, there is a set $\{t_1, t_2, \dots, t_m\}$ of m boolean type attributes indicating wether or not a tuple belongs to subclass S_i.

Object-Relational Mapping (ORM)

- **Object-relational mapping** (**ORM**) uses different tools, technologies and techniques to map data objects in a target programming language to relations and tables of a RDBMS
- An ORM solution consists of the following four pieces:

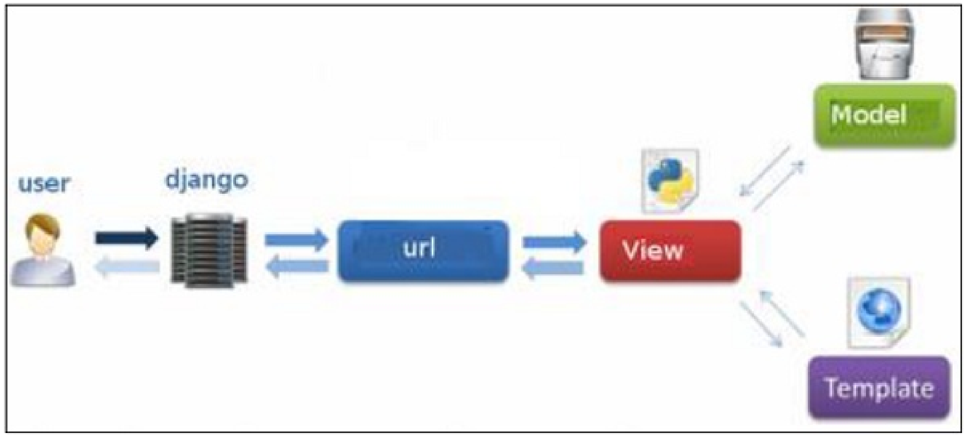


ORM solutions

- An ORM abstracts your application away from the underlying SQL database and SQL dialect
- If the tool supports a number of different databases (and most do), this confers a certain level of portability on your application
- Several programming languages have at least one ORM solution
  - Java: it provides both a standard specification, named Java Persistence API (JPA), and several implementations of the specification (Hibernate, EclipseLink)
  - C++: possible ORM solutions are
    - ODB: https://www.codesynthesis.com/products/odb
    - QxOrm: https://www.qxorm.com/qxorm_en/home.html
  - Python:
    - **SQLAlchemy**: https://www.sqlalchemy.org/
    - The **Django** framework: https://docs.djangoproject.com/en/2.1/topics/db/
    - Pony: https://ponyorm.com/
  - Ruby: ActiveRecord, DataMapper, Sequel
  - Rust: SeaORM, Diesel, rbatis

Django

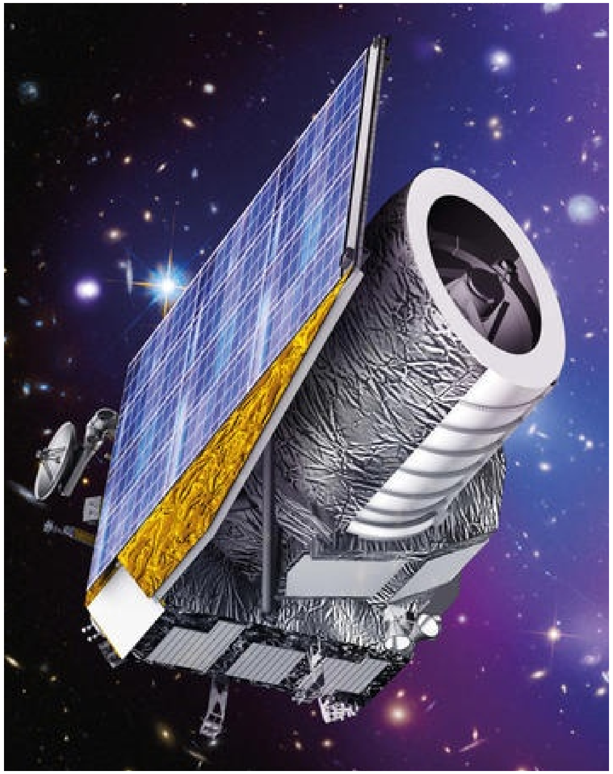
- Django is a high-level Python Web framework that encourages rapid development and clean, pragmatic design https://www.djangoproject.com
- Django follows the model-template-view (MTV) architectural pattern
  - An object-relational mapper, defining a data model as python classes (**Models**)
  - A system for processing HTTP requests (**Views**) with a web templating sytem (**Template**)
  - A regular-expression-based URL dispatcher (**Url**)



- Django comes with a lightweight standalone web server for development and testing
- A serialization system that can produce and read XML and/or JSON representation of Django models
- Lot of reusable packages provided by the community: https://djangopackages.org/

Example from the Euclid mission

- M2 mission in the framework of **ESA Cosmic Vision Program**
- Euclid mission objective is to map the geometry and understand the nature of the **dark Universe** (dark energy and dark matter)
- **Federation** of 8 European + 1 US Science Data Centers and a Science Operation Center (ESA)
- Large amount of data produced by the mission
  - Due to reprocessing
  - Large amount of **external data** needed (ground based observations)
  - Grand total: 3**0 PB**
- Two instruments on board:
  - VIS: Visible Imager
  - NISP: Near Infrared Spectro-Photometer



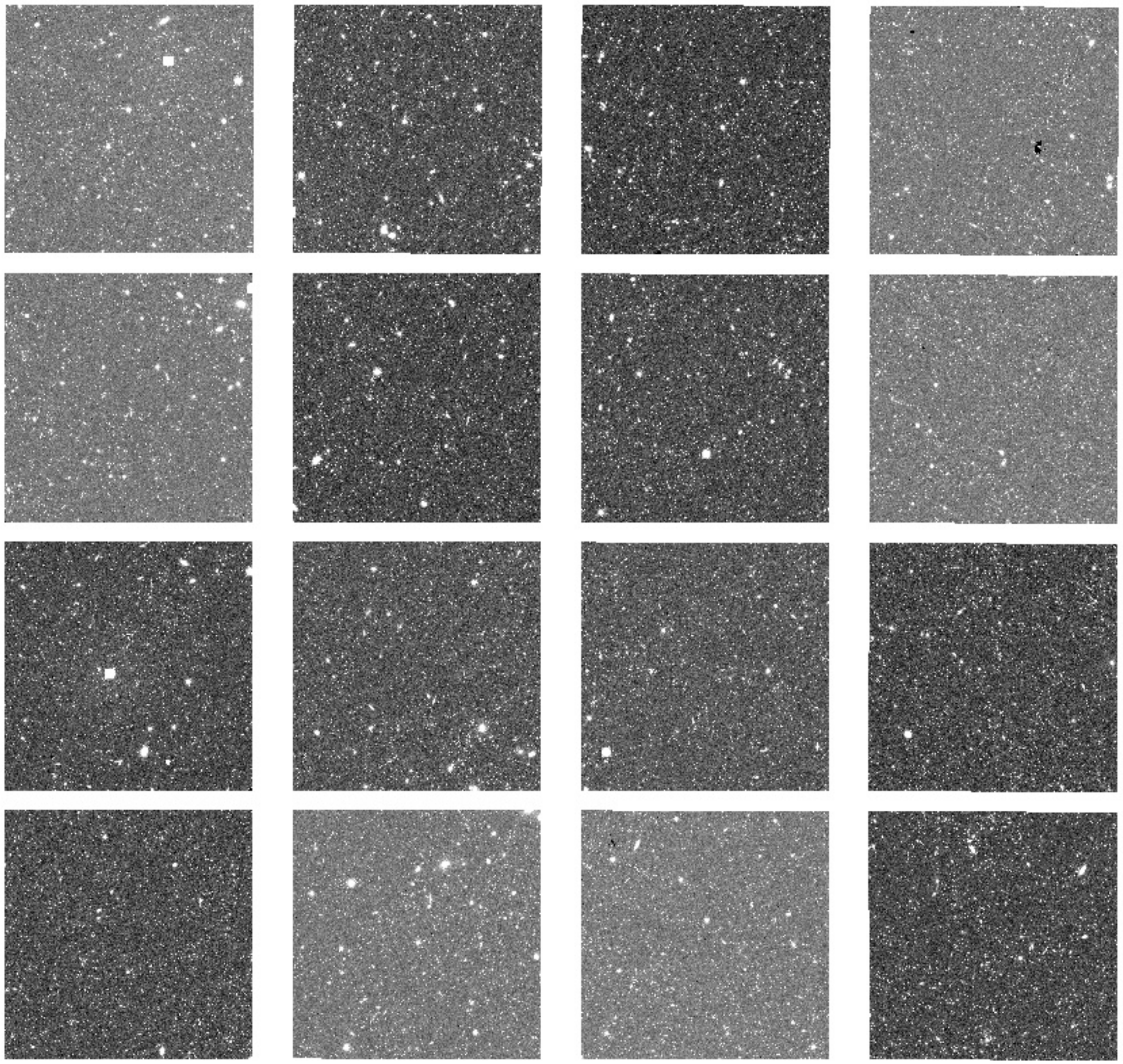
A NISP instrument simulated image

The NISP focal plane is composed of a matrix of 4×4 2040×2040 18 micron pixel detectors

The photometric channel is equipped with 3 broad band filters (Y, J and H)

The spectroscopic channel is equipped with 4 different low resolution near infrared grisms (three red and one blue) but no slit

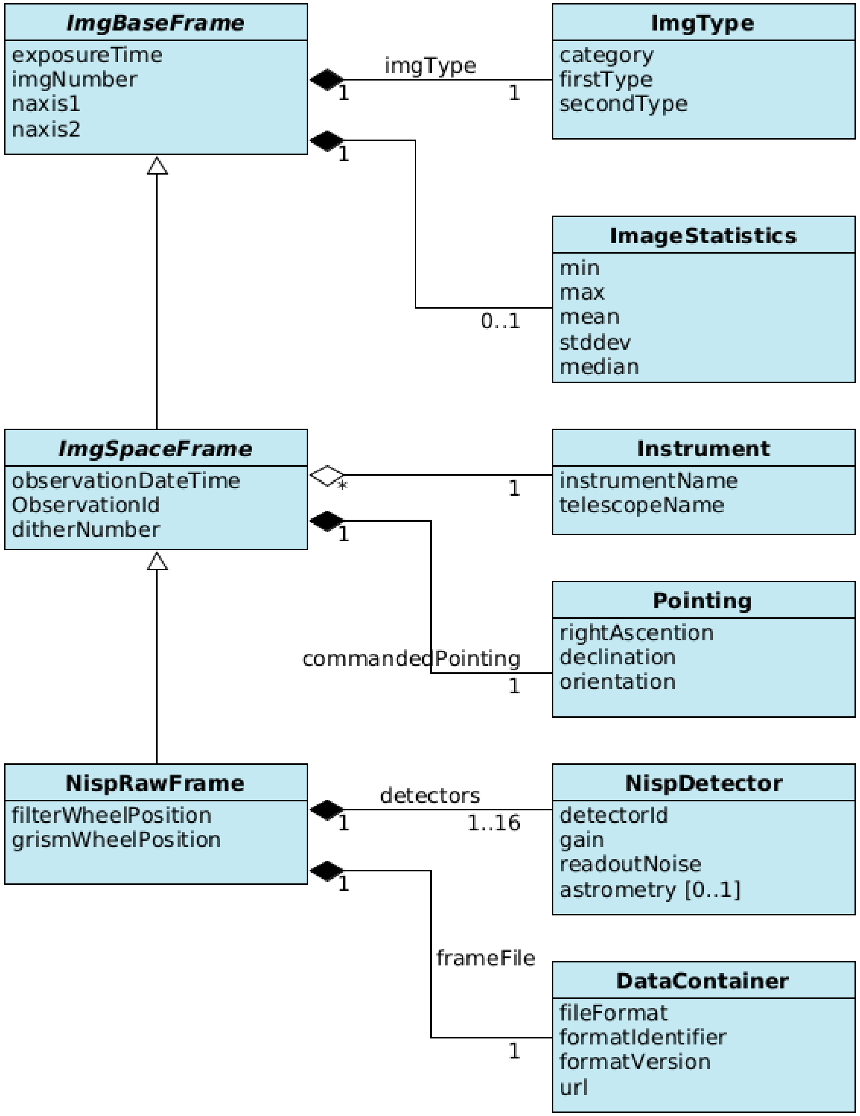
The image on the right shows a NISP frame composed by its 16 detectors (photometric channel, 1 band)



Metadata content (simplified)

- We need to define the metadata associated to a NISP image (a single exposure)
- Since Euclid also needs images from **ground-based telescopes**, the **dictionary** of types used to model the metadata information should be homogeneous among them and **reuse** a **common base set** of type definitions
- All images have a common set of information
  - **Exposure time**, **image category** and purpose (is it a simulation, a calibration image, a sky image, etc.) and image **dimensions**, some statistics on the image, to quickly check if there are anomalies, and we need to keep the information about the **instrument** used to acquire a given image
  - However, for ground-based telescopes we need also the geographical location of the telescope, so the telescope information requires more properties.
  - Space telescopes can perform **surveys** of the sky, hence the observation can be identified by the **observation ID**. Moreover, for a given field, they can execute a **dithering** pattern, in order to increase the signal-to-noise ratio and reduce cosmic-ray hits. So we need also to store the dither number. Additional information needed are the **observation date and time** and the **commanded pointing** (right ascension, declination and telescope orientation)
- Then we have information specific to the Euclid instruments. The NISP instrument has both a filter wheel and a grism wheel. The images from **all detectors** should be stored in a single file, to simplify its retrieval and the analysis. However, each detector has some specific properties: **gain**, **readout noise**. Then, for each detector we need to compute the mapping from pixel indexes to sky coordinates (RA, DEC), i.e. its own **astrometric solution**.

The NISP image data model (simplified)



Django Implementation (1)

- Each class inherits models.Model
- All fields use a Django Model Data Type
  https://www.webforefront.com/django/modeldatatypesandvalidation.html
  - models.CharField(max_length = 20)
  - models.BooleanField()
  - models.FloatField()
  - models.DateTimeField()
  - …
- Attributes in the Data Model Type are used to set options for fields
  - null = True
  - primary_key = True
- Foreign keys
  https://docs.djangoproject.com/en/5.0/ref/models/fields/#django.db.models.ForeignKey

```
instrument = models.ForeignKey(Instrument)
```

- Related names
  https://docs.djangoproject.com/en/5.0/topics/db/queries/#backwards-related-objects

```
rawFrame = models.ForeignKey('NispRawFrame', related_name='detectors', on_delete=models.CASCADE)
```

Django Implementation (2)

- By **enumerated type** we mean a type that provides a set of possible values through the **`choices`** parameter (option) available to all field types

```
IMAGE_CATEGORY = ( 'SCIENCE', 'CALIBRATION', 'SIMULATION')

category = models.CharField( max_length=20, choices=[(d, d) for d in IMAGE_CATEGORY])
```

- Model Meta options is “anything that’s not a field”
  - Abstract class
  - Ordering
  - Candidate key of multiple columns
  - ...

```
class Meta:
    abstract = True

class Meta:
    ordering = ['surname']

class Meta:
    unique_together = (("fiscalCode1", "fiscalCode2"),)
```

- It is a good practice to override the default name of objects

```
def __str__(self):
        return self.name
```

Prerequisites

- The simplest way to install Django is to download and install the Python Anaconda Distribution, with Python version 3.x: https://www.anaconda.com/download
- Then you need to install some additional python packages for the following exercise/hands-on:
  - To install the Django framework use the following command line:

```
conda create -n orm_django django
```

  - Additional packages are needed, not available in Anaconda but installed with the "pip" command:

```
pip install django-extensions djangorestframework
pip install django-composite-field django-ufilter
pip install django-phonenumber-field phonenumbers
pip install Pillow
```

  - The full Anaconda distribution already provides Jupyter notebooks, used in one example

ORM project example - Euclid

- The entire examples can be retrieved at the following link:

  https://www.ict.inaf.it/gitlab/odmc/orm_example

- You can clone the project with the git version control system, i.e. with the command:

```
git clone https://www.ict.inaf.it/gitlab/odmc/orm_example.git
cd orm_example/django_example_euclid
```

- The Diango project for the Euclid example has been already created using the following commands (so you **don’t need** to execute them):

```
django-admin startproject euclid_example ./
python manage.py startapp imagedb
```

which creates a project folder, named **euclid_example**, with additional files and then an application, named **imagedb**, inside the project.
It automatically creates skeleton files needed by a django project and application

Project structure

```
django_example_euclid/
├── imagedb
│   ├── admin.py
│   ├── apps.py
│   ├── migrations
│   ├── models.py
│   ├── tests.py
│   └── views.py
├── manage.py
└── euclid_example
    ├── settings.py
    ├── urls.py
    └── wsgi.py
```

File containing the app data model

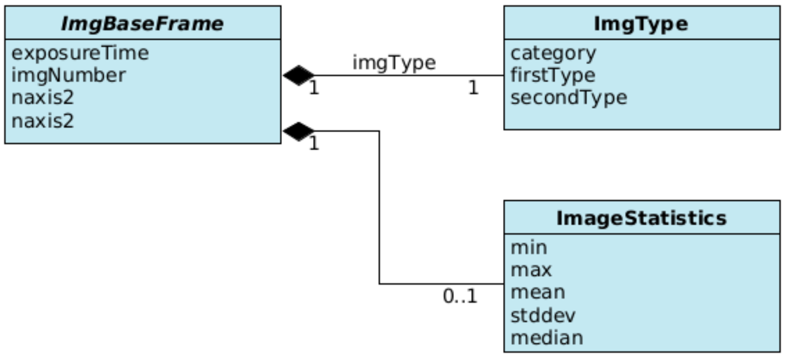
Views on the data model classes

Project settings: app list and configuration

Site urls declaration

The Django ORM

- From the data model class to a Django ORM model class



- Each model is represented by a class that subclasses **django.db.models.Model**
- ImageBaseFrame here is **abstract**: no table instantiated
  - That's why we define the stats attribute as a Foreign Key to the ImageStatistics class and not vice versa

```python
from django.db import models

class ImageBaseFrame(models.Model):
  exposureTime = models.FloatField()
  imgNumber = models.PositiveSmallIntegerField()
  naxis1 = models.PositiveIntegerField()
  naxis2 = models.PositiveIntegerField()
  imageType = ImageType()
  stats = models.OneToOneField(
    ImageStatistics,
    models.SET_NULL,
    blank=True,
    null=True,
  )

  class Meta:
    abstract = True
```

Composite fields

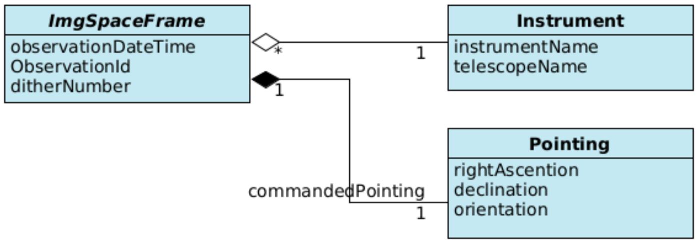
- Sometime we would like to define a model class attribute as a **multi-column field** in the same table (i.e. a non-atomic type) instead of creating a 1-to-1 relation (a second table with the attribute columns and a foreign key)
- Many ORM systems provide such feature:
  - JPA: named as **embeddable classes**
  - odb: named as **Composite Value Types**
  - SQLAlchemy: named as **Composite Column Types**
- Django ORM does not provide directly this feature. However there is a package provided by the community, called django-composite-field, which provides an “acceptable” solution
- Composite fields provide an implementation of a “part-of” relationship, i.e. what in the UML class diagram is called **composition**

The ImageType class

```python
IMAGE_CATEGORY = (
  'SCIENCE',
  'CALIBRATION',
  'SIMULATION'
)

IMAGE_FIRST_GROUP = (
  'OBJECT',
  'STD',
  'BIAS',
  'DARK',
  'FLAT',
  'LINEARITY',
  'OTHER'
)


IMAGE_SECOND_GROUP = (
  'SKY',
  'LAMP',
  'DOME',
  'OTHER'
)
```

```python
from composite_field import CompositeField

class ImageType(CompositeField):

  category = models.CharField(
    max_length=20,
    choices=[(d, d) for d in IMAGE_CATEGORY]
  )

  firstType = models.CharField(
    max_length=20,
    choices=[(d,d) for d in IMAGE_FIRST_GROUP]
  )

  secondType = models.CharField(
    max_length=20,
    choices=[(d,d) for d in IMAGE_SECOND_GROUP]
  )
```

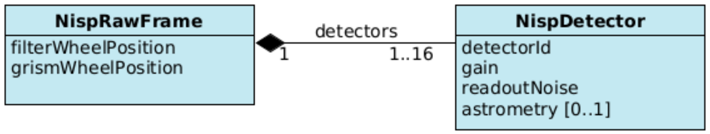
The ImageSpaceFrame class




```python
class Instrument(models.Model):
  instrumentName = models.CharField(max_length=100)
  telescopeName = models.CharField(max_length=100)


class Pointing(CompositeField):
  rightAscension = models.FloatField()
  declination = models.FloatField()
  orientation = models.FloatField()


class ImageSpaceFrame(ImageBaseFrame):
  observationDateTime = models.DateTimeField()
  observationId = models.PositiveIntegerField()
  ditherNumber = PositiveSmallIntegerField()
  instrument = models.ForeignKey(Instrument,
                                 on_delete=models.CASCADE)
  commandedPointing = Pointing()

  class Meta:
    abstract = True
```

- The same Instrument is associated to many images, hence here we use a Foreign Key from `ImageSpaceFrame` to `Instrument`
- If the Instrument instance is deleted, also all images referring to it are automatically deleted (option **on_delete** set to models.CASCADE in ForeignKey)

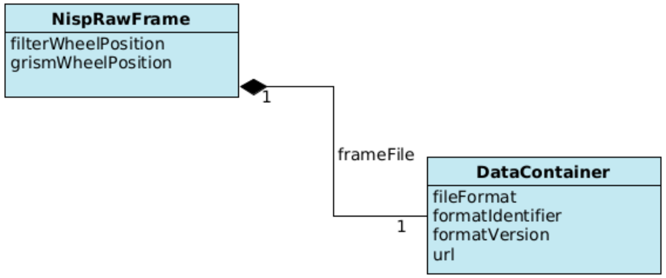
NispDetector




```python
NISP_DETECTOR_ID = (
  '11','12','13','14',
  '21','22','23','24',
  '31','32','33','34',
  '41','42','43','44'
)


class NispDetector(models.Model):
  detectorId = models.CharField(
    max_length=2,
    choices = [(d,d) for d in NISP_DETECTOR_ID]
  )
  gain = models.FloatField()
  readoutNoise = models.FloatField()
  rawFrame = models.ForeignKey('NispRawFrame',
                               related_name='detectors',
                               on_delete=models.CASCADE)
```

- Many detectors (up to 16) associated to the same raw frame
- Since NispRawFrame is not yet defined, we pass the class name as a string to models.ForeignKey
- But we want to access the detector data using the NispRawFrame class, i.e. the reverse relation.
- This is the purpose of the related_name parameter. For instance we can access the detector data using NispRawFrame.detectors

NispRawFrame class




```
NISP_FILTER_WHEEL = (
  'Y',
  'J',
  'H',
  'OPEN',
  'CLOSE'
)

NISP_GRISM_WHEEL = (
  'BLUE0',
  'RED0',
  'RED90',
  'RED180'
  'OPEN'
  'CLOSE'
)
```

```
class DataContainer(models.Model):
  fileFormat = models.CharField(
    max_length=10
  )
  formatIdentifier = models.CharField(
    max_length=20
  )
  formatVersion = models.CharField(
    max_length=20
  )
  url = models.URLField()


class NispRawFrame(ImageSpaceFrame):
  filterWheelPosition = models.CharField(
    max_length=10,
    choices = [(d,d) for d in NISP_FILTER_WHEEL]
  )

  grismWheelPosition = models.CharField(
    max_length=10,
    choices = [(d,d) for d in NISP_GRISM_WHEEL]
  )
  frameFile = models.OneToOneField(DataContainer,
                                   on_delete=models.CASCADE)
```

- A models.OneToOneField is analogous to models.ForeignKey with the option unique=True but the reverse side of the relation will directly return a single object

DB Schema creation 1/2

- Once we have defined our data model in **imagedb/models.py** we need Django to create the corresponding DB schema
- First let's check the the project settings includes the imagedb application, i.e. that the file **orm_example/settings.py** contains the the strings highlighted in red in the box on the bottom left
- To do the first migration, i.e. generation of the DB schema, **run the following command**

command

```
python manage.py makemigrations imagedb
```

output

```
Migrations for 'imagedb':
  imagedb/migrations/0001_initial.py
    - Create model DataContainer
    - Create model ImageStatistics
    - Create model Instrument
    - Create model NispRawFrame
    - Create model NispDetector
    - Create model Astrometry
```

```
INSTALLED_APPS = [
    'django.contrib.admin',
    'django.contrib.auth',
    'django.contrib.contenttypes',
    'django.contrib.sessions',
    'django.contrib.messages',
    'django.contrib.staticfiles',
    'django_extensions',
    'imagedb',
    'rest_framework',
    'django_ufilter',
]
```

Then run the command

```
python manage.py migrate
```

DB Schema creation 2/2

imagedb_astrometry	[table]
id	INTEGER NOT NULL auto-incremented
ctype1_coordinateType	VARCHAR(4) NOT NULL
ctype1_projectionType	VARCHAR(3) NOT NULL
ctype2_coordinateType	VARCHAR(4) NOT NULL
ctype2_projectionType	VARCHAR(3) NOT NULL
crval1	REAL NOT NULL
crval2	REAL NOT NULL
crpix1	REAL NOT NULL
crpix2	REAL NOT NULL
cd1_1	REAL NOT NULL
cd1_2	REAL NOT NULL
cd2_1	REAL NOT NULL
cd2_2	REAL NOT NULL
detector_id	BIGINT

imagedb_nispdetector	[table]
id	INTEGER NOT NULL auto-incremented
detectorId	VARCHAR(2) NOT NULL
gain	REAL NOT NULL
readoutNoise	REAL NOT NULL
rawFrame_id	BIGINT NOT NULL

imagedb_nisprawframe	[table]
id	INTEGER NOT NULL auto-incremented
exposureTime	REAL NOT NULL
imgNumber	SMALLINT UNSIGNED NOT NULL
naxis1	INTEGER UNSIGNED NOT NULL
naxis2	INTEGER UNSIGNED NOT NULL
imageType_category	VARCHAR(20) NOT NULL
imageType_firstType	VARCHAR(20) NOT NULL
imageType_secondType	VARCHAR(20) NOT NULL
observationDateTime	DATETIME NOT NULL
observationId	INTEGER UNSIGNED NOT NULL
ditherNumber	SMALLINT UNSIGNED NOT NULL
commandedPointing_rightAscension	REAL NOT NULL
commandedPointing_declination	REAL NOT NULL
commandedPointing_orientation	REAL NOT NULL
filterWheelPosition	VARCHAR(15) NOT NULL
grismWheelPosition	VARCHAR(15) NOT NULL
frameFile_id	BIGINT NOT NULL
instrument_id	BIGINT NOT NULL
stats_id	BIGINT

imagedb_datacontainer	[table]
id	INTEGER NOT NULL auto-incremented
fileFormat	VARCHAR(10) NOT NULL
formatIdentifier	VARCHAR(20) NOT NULL
formatVersion	VARCHAR(20) NOT NULL
url	VARCHAR(200) NOT NULL

imagedb_instrument	[table]
id	INTEGER NOT NULL auto-incremented
instrumentName	VARCHAR(100) NOT NULL
telescopeName	VARCHAR(100) NOT NULL

imagedb_imagestatistics	[table]
id	INTEGER NOT NULL auto-incremented
min	REAL NOT NULL
max	REAL NOT NULL
mean	REAL NOT NULL
stddev	REAL NOT NULL
median	REAL NOT NULL

Data insertion

- We can now open a python shell and interact with the data model API

```
python manage.py shell
```

```
Python 3.7.0 (default, Jun 28 2018, 13:15:42)
Type 'copyright', 'credits' or 'license' for more information
IPython 6.5.0 -- An enhanced Interactive Python. Type '?' for help.

In [1]: from imagedb.models import Instrument

In [2]: instrument = Instrument(telescopeName='Euclid', instrumentName='VIS')

In [3]: instrument.save()

In [4]: quit()
```

- We can pass a Python script to insert data

```
python manage.py shell < data_ingestion.py
```

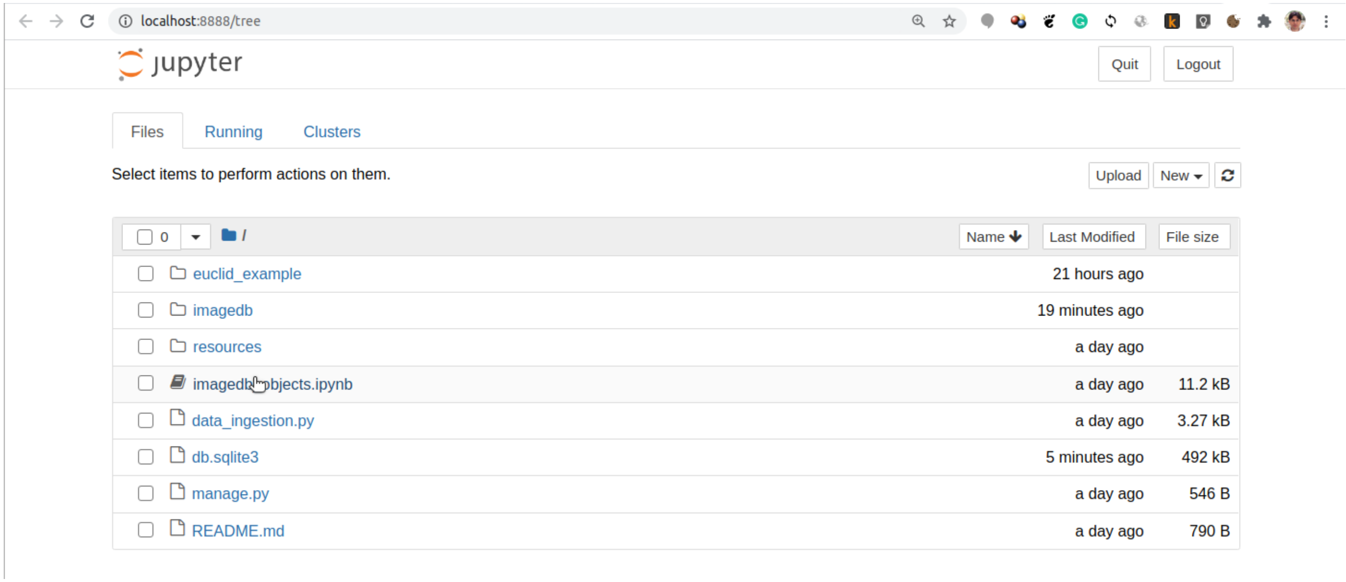
```
2025-06-21T17:14:03.000001
2025-06-21T12:20:43.000001
2025-06-22T17:42:53.000001
…
```

Django ORM and Jupyter notebook

- For didactic purpose, we can use a Django extension to start a Jupyter notebook. The orm_example project example already provides one notebook. To use it, issue the following command:

```
env DJANGO_ALLOW_ASYNC_UNSAFE=true python manage.py shell_plus --lab
```

a browser page will be opened. In this page, select the file **imagedb_objects.ipynb** and execute each cell.

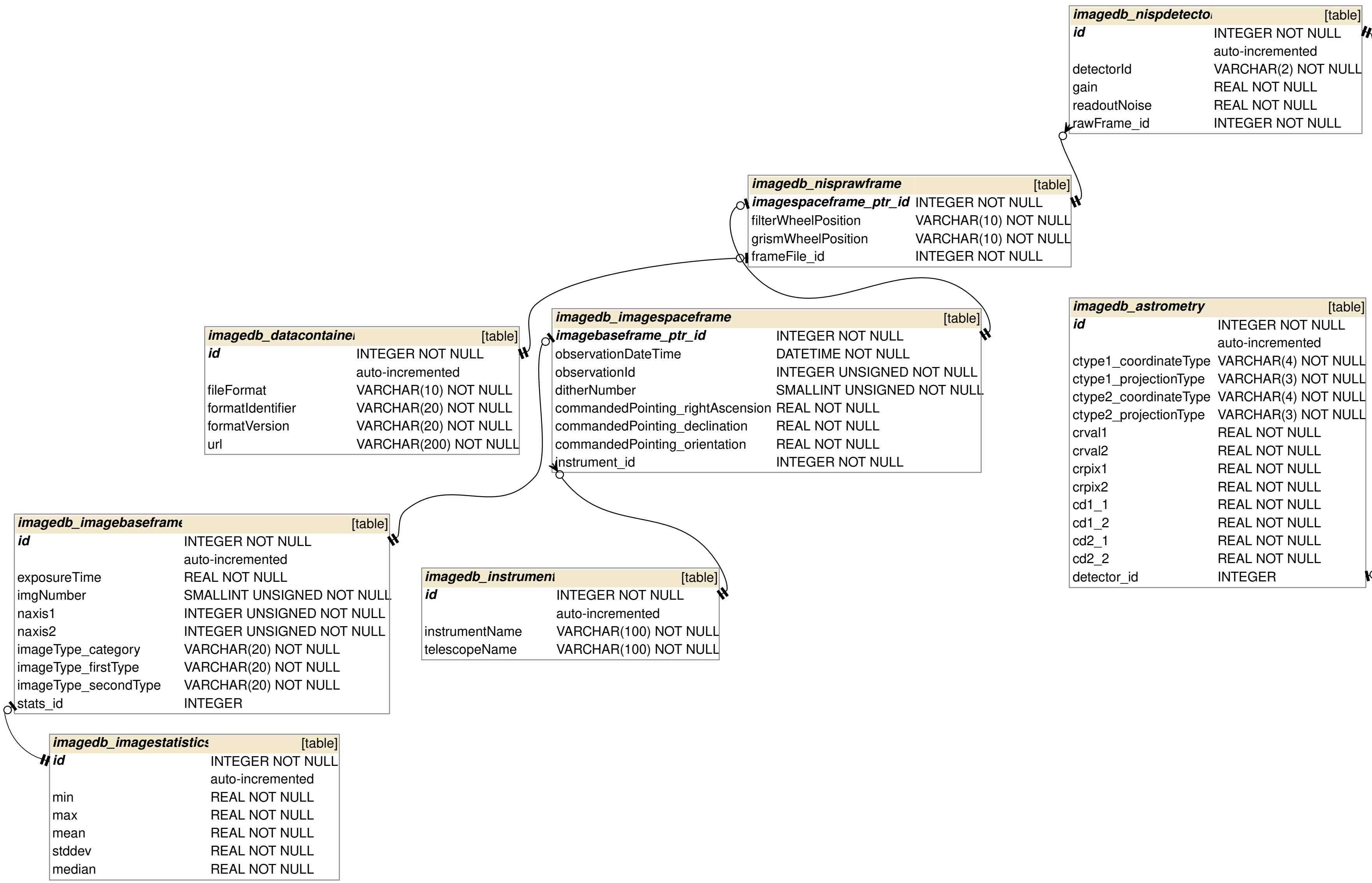


Multi-table inheritance 1/3

- With django model abstract base classes, we cannot define foreign keys referencing such base class (since no table is created for abstract classes)
- A solution is the **Multi-table inheritance** of Django models. In this case the abstraction is removed from such base classes and each class in the inheritance hierarchy will have a corresponding table in the DB schema.
- To obtain a multi-table inheritance version of the previous data model, remove the statements

```
class ImageBaseFrame(models.Model):
  ...

  class Meta:
    abstract = True

class ImageSpaceFrame(ImageBaseFrame):
  ...

  class Meta:
    abstract = True
```

Multi-table inheritance 2/3



Multi-table inheritance 3/3

- Each model corresponds to its own database table and can be queried and created individually
- The inheritance relationship introduces links between the child model and each of its parents (via an automatically-created **OneToOneField**)
- With the multi-table inheritance, all fields of **ImageBaseFrame** will still be available also in **ImageSpaceFrame** and **NispRawFrame**
- If we have an ImageBaseFrame instance that is also an ImageSpaceFrame instance, we can get from ImageBaseFrame object to ImageSpaceFrame object by using the lower-case version of the model name

```
from imagedb.models import ImageBaseFrame

obj = ImageBaseFrame.objects.get(pk=2)
obj.imagespaceframe.nisprawframe
```

```
<NispRawFrame: NispRawFrame object (2)>
```

Serializing Django objects

- Django’s serialization framework provides a mechanism for “translating” Django models into other formats.
- Usually these other formats will be text-based and used for sending Django data over a wire, but it’s possible for a serializer to handle any format (text-based or not).
- Django supports a number of serialization formats, including XML and JSON.

```
from django.core import serializers

serializers.serialize('json',NispRawFrame.objects.filter(observationId=53877,
                                filterWheelPosition='Y').order_by('ditherNumber'))
```

- The Django serialize function requires, as one of the inputs, a **QuerySet**
- However, the **Django REST framework**, external to the Django framework, provides a more flexible serialization mechanism

The Django REST serializers

- In particular, the Django REST framework provides a **ModelSerializer** class which can be a useful shortcut for creating serializers that deal with model instances and querysets
- See ‘imagedb/serializers.py’ to check some examples

```
from rest_framework import serializers
from composite_field.rest_framework_support import CompositeFieldSerializer

...

class NispRawFrameSerializer(serializers.ModelSerializer):
  detectors = NispDetectorSerializer(many = True, read_only = True)
  commandedPointing = CompositeFieldSerializer()
  imageType = CompositeFieldSerializer()

  class Meta:
    model = NispRawFrame
    exclude = [f.name for g in NispRawFrame._meta.get_fields()
               if hasattr(g, 'subfields')
               for f in g.subfields.values()]
    depth = 2
```

The Django REST framework

- We need an Application Programming Interface (API) that let us perform CRUD operations on the database without directly connecting to the database
- A REST (Representational State Transfer) API provides such operations through HTTP methods:
  - GET, to request to a server a specific dataset
  - POST, to create a new data object in the database
  - PUT, to update an existing object in the database or create it if it does not exist
  - DELETE, to request the removal of a given data object
- Such methods can be applied to a specific set of endpoints (URLs) provided by our API
- The Django REST framework provides software tools to build a REST API on top of our models

Django REST framework ViewSets

- The actions provided by the **ModelViewSet** class are .list(), .retrieve(), .create(), .update(), .partial_update(), and .destroy() of instances of a specific model we have defined
- The **ReadOnlyModelViewSet** only provides the 'read-only' actions, .list() and .retrieve()
  - In practice it returns a list of instances of a specific model or it retrieves a single instance by its primary key value
- In our orm_example projects, we have few examples in **imagedb/views.py**

```
from rest_framework import viewsets
from imagedb.serializers import NispRawFrameSerializer

class NispRawFrameViewSet(viewsets.ReadOnlyModelViewSet):
  queryset = NispRawFrame.objects.all()
  serializer_class = NispRawFrameSerializer
```

- More advanced filtering capabilities can be added with additional parameters: https://www.django-rest-framework.org/api-guide/filtering/

URLs

- Once we have defined viewsets on our models, we have to create endpoints (urls) to access those views
- The Django REST framework provides the so called **routers**, which generate automatically url patterns based on the views we have defined
- An example is found in **imagedb/urls.py**

```
from django.urls import re_path, include
from rest_framework.routers import DefaultRouter

from imagedb import views

router = DefaultRouter()
router.register(r'nisprawframes', views.NispRawFrameViewSet)

urlpatterns = [
  re_path(r'^', include(router.urls))
]
```

will generate automatically the following url patterns:
/nisprawframes/ : it will return, in json format, all the NispRawFrame objects in the database
/nisprawframes/[pk]/ : it will return only the NispRawFrame object with primary key pk

Starting the Django development server

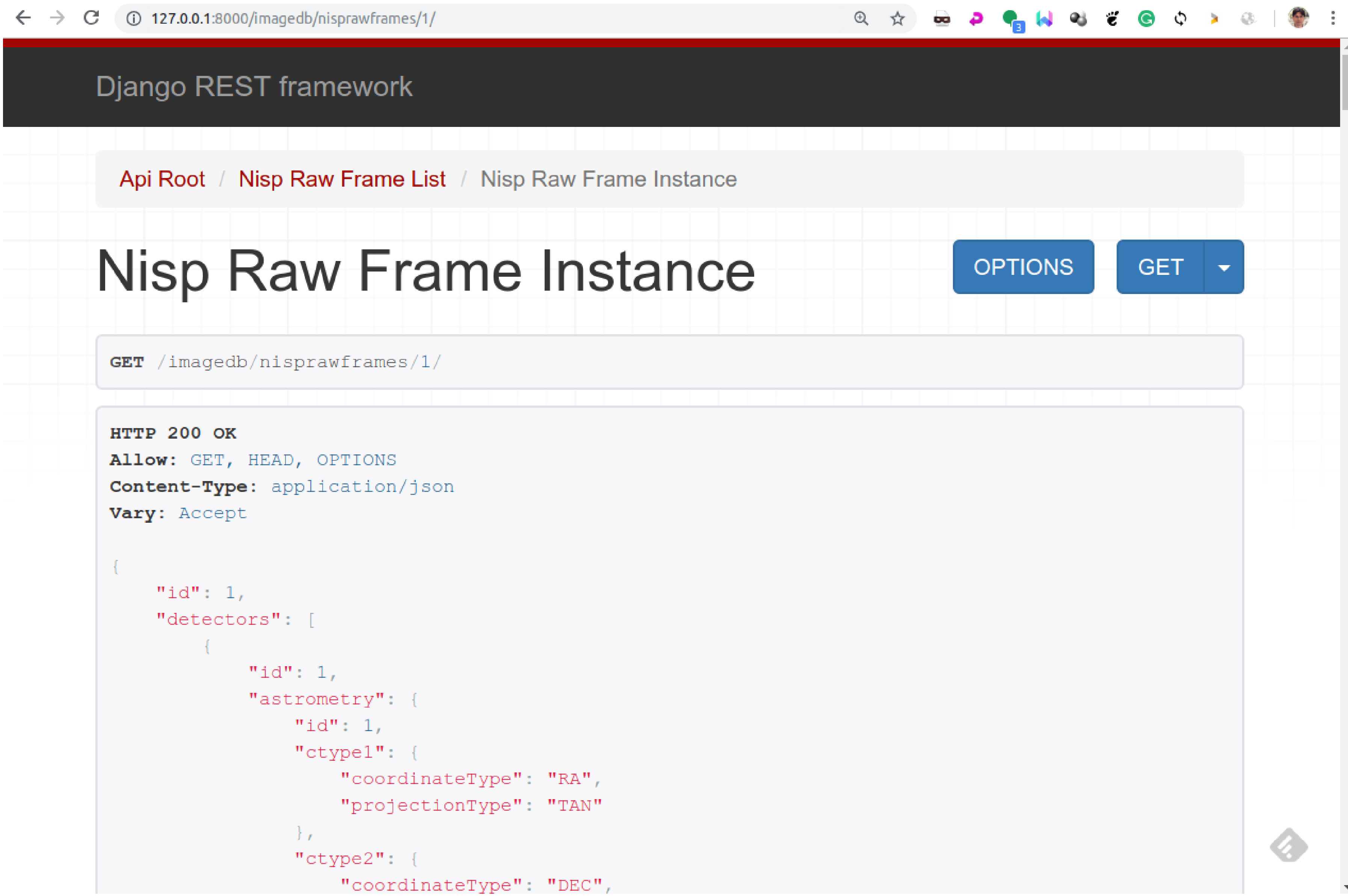
- In order to test the REST API, you can start the Django server with the following command

```
python manage.py runserver
```

```
Performing system checks...

System check identified no issues (0 silenced).
October 15, 2018 - 21:30:57
Django version 2.1.1, using settings
'orm_example.settings'
Starting development server at
http://127.0.0.1:8000/
Quit the server with CONTROL-C.
```

- Now with the browser you can open the following link: http://127.0.0.1:8000/imagedb/nisprawframes/1/

The browsable REST API

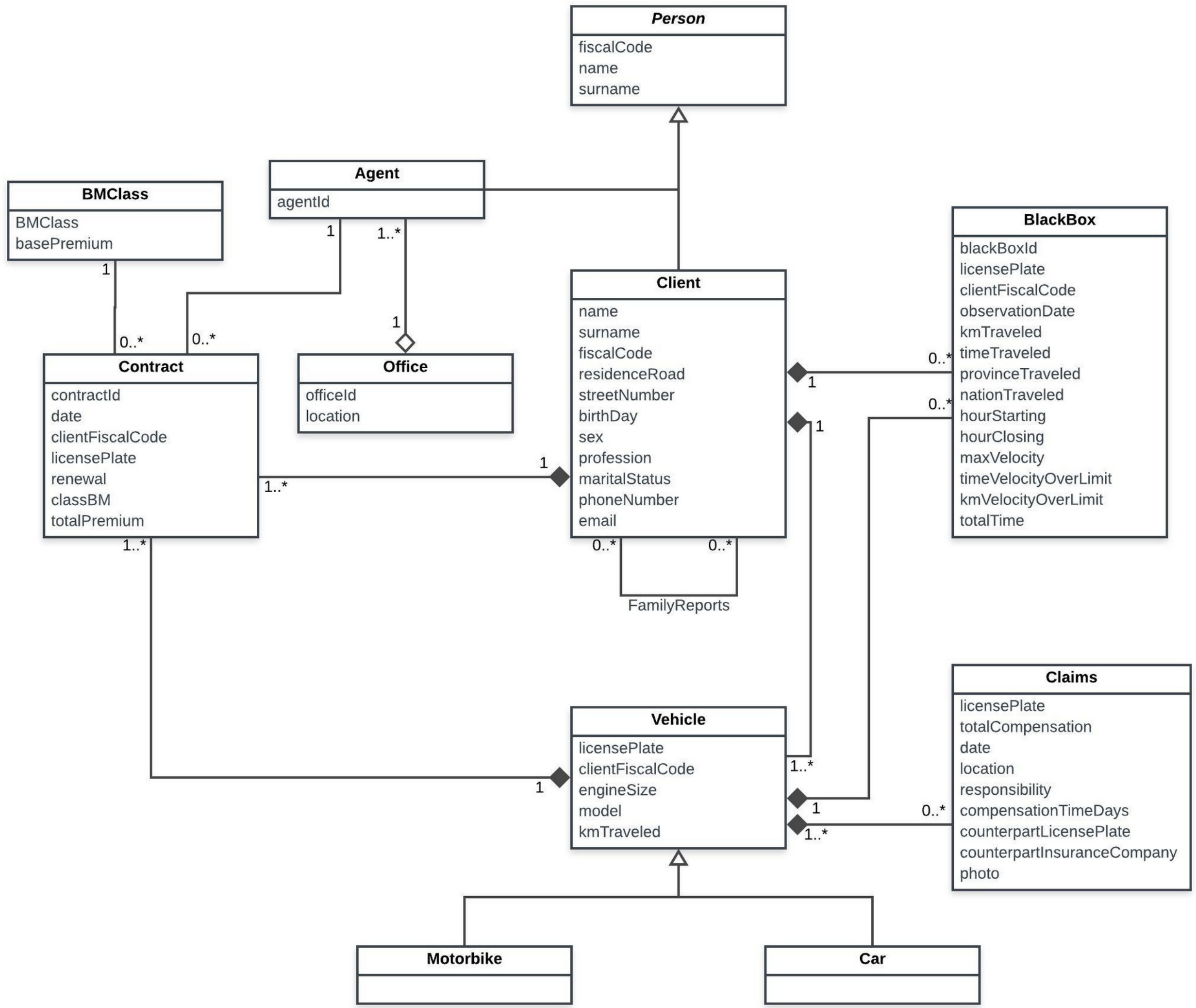


More advanced filtering criteria

- In order to use more advanced filtering criteria through the REST API, rather then just the primary key, in the orm_example project we have added the **django-ufilter** (https://github.com/Qu4tro/django-ufilter/)
- With this filter, we can specify filtering condition directly in the url, e.g. :

```
http://127.0.0.1:8000/imagedb/nisprawframes/?observationId__in=53877,54349&filterWheelPosition=Y
```

Data Model for Insurance Company



Credit to Andrea Pesce

Identifiers

Identifier for Contracts

Element of interest	Value
name	First three letters
surname	First three letters
date	Day, Month, Year (e.g.: 130394 for 13 March 1994)
renewal number	0 (for first contract),1,2,3,…
province	ISO Code
uniqueness	Random character

Identifier for FamilyReports

Element of interest	Value
first relative	fiscalCode
second relative	fiscalCode

ORM project example

- The entire example can be retrieved at the following link:

  https://www.ict.inaf.it/gitlab/odmc/orm_example

- You can clone the project with the git version control system, i.e. with the command:

```
git clone https://www.ict.inaf.it/gitlab/odmc/orm_example.git
cd orm_example/django_example_insurance
```

- Create the Diango project from scratch using the following commands

```
django-admin startproject insurance
cd insurance
python manage.py startapp insurancedb
```

which creates a project folder, named **insurance**, with additional files and then an application, named **insurancedb**, inside the project.
It automatically creates skeleton files needed by a Django project and application

Project structure

```
insurance/
├── insurancedb
│   ├── admin.py
│   ├── apps.py
│   ├── migrations
│   ├── models.py
│   ├── tests.py
│   └── views.py
├── manage.py
└── insurance
    ├── settings.py
    ├── urls.py
    └── wsgi.py
```

- admin.py: File configuring the Admin site
- models.py: File containing the app data model
- views.py: Views on the data model classes
- settings.py: Project settings: app list and configuration
- urls.py: Site urls declaration

- For admin.py, models.py, urls.py and views.py files we are going to use the ones in the git repository
- We must edit the settings.py

DB Schema creation

- Once we have defined our data model in **insurancedb/models.py** we need Django to create the corresponding DB schema
- First let's check the the project settings includes the insurancedb application, i.e. that the file **insurance/settings.py** contains the strings highlighted in red in the box on the bottom left
- To do the first migration, i.e. generation of the DB schema, **run the following command**

command

```
python manage.py makemigrations insurancedb
```

output

```
Migrations for 'insurancedb':
  insurancedb/migrations/0001_initial.py
    - Create model BMClass
    - Create model Client
    - Create model Office
    - Create model Vehicle
    - Create model Contract
    - Create model Claims
    - Create model BlackBox
    - Create model Agent
    - Create model FamilyReports
```

```
INSTALLED_APPS = [
    'django.contrib.admin',
    'django.contrib.auth',
    'django.contrib.contenttypes',
    'django.contrib.sessions',
    'django.contrib.messages',
    'django.contrib.staticfiles',
    'django_extensions',
    'insurancedb',
]
```

Then run the command

```
python manage.py migrate
```

Data insertion

- We can now open a python shell and interact with the data model API

```
python manage.py shell
```

```
Python 3.7.0 (default, Jun 28 2018, 13:15:42)
Type 'copyright', 'credits' or 'license' for more information
IPython 6.5.0 -- An enhanced Interactive Python. Type '?' for help.

In [1]: from insurancedb.models import BMClass

In [2]: bonus = BMClass(BMClass=1, basePremium=100.00)

In [3]: bonus.save()

In [4]: quit()
```

- You can pass a Python script to insert data

```
python manage.py shell < ../insert.py
```

Django urls.py and views.py

- A clean, elegant URL scheme is an important detail in a high-quality Web application. Django lets you design URLs however you want, with no framework limitations
- To design URLs for an app, you create a Python module informally called a URLconf (URL configuration). This module is pure Python code and is a mapping between URL path expressions to Python functions (your views)
- A view function, or view for short, is simply a Python function that takes a Web request and returns a Web response. This response can be:
  - HTML contents
  - A redirect
  - A 404 error
  - An XML document
  - An image
  - ...

```
from django.http import HttpResponse
import datetime

def current_datetime(request):
    now = datetime.datetime.now()
    html = "<html><body>It is now %s.</body></html>" % now
    return HttpResponse(html)
```

Django admin.py

- Django provides an automatic admin interface
- It reads metadata from your models to provide a quick, model-centric interface where trusted users can manage content on your site
- You can customize the admin interface editing the admin.py
- Setup an admin user

```
python manage.py createsuperuser
```

- Run the Django web server

```
python manage.py runserver
```

- Access to http://127.0.0.1:8000/

ADDITIONAL MATERIAL

SQLAlchemy (1)

- The SQLAlchemy SQL Toolkit and Object Relational Mapper is a comprehensive set of tools for working with databases and Python
- It provides a full suite of well-known enterprise-level persistence patterns, designed for efficient and high-performing database access
- SQLAlchemy has dialects for many popular database systems including Firebird, Informix, Microsoft SQL Server, MySQL, Oracle, PostgreSQL, SQLite, or Sybase
- The SQLAlchemy has four ways of working with database data:
  - Raw SQL
  - SQL Expression Language
  - Schema Definition Language
  - ORM

SQLAlchemy (2)

- SQLAlchemy ORM consists of several components
  - **Engine**
    - It manages the connection with the database
    - It is created using the create_engine() function
  - Declarative **Base** class
    - It maintains a catalog of classes and tables
    - It is created using the declarative_base() function and is bound to the engine
  - **Session** class
    - It is a container for all conversations with the database
    - It is created using the sessionmaker() function and is bound to the engine
- https://docs.sqlalchemy.org/en/14/orm/tutorial.html

Prerequisites

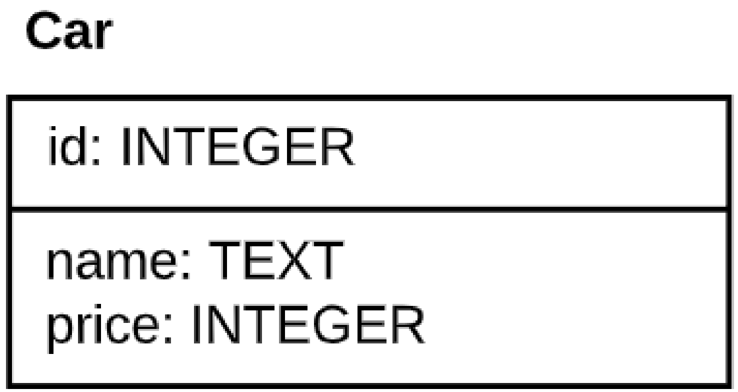
- Download and install the Python Anaconda (or Miniconda) Distribution, with Python version 3.x: https://www.anaconda.com/download
- Then you need to install some additional python packages for the following exercise/hands-on:
  - To install the Django framework use the following command line:

```
conda create -n orm_sqlalchemy sqlalchemy
conda activate orm_sqlalchemy
```

- Clone the GIT repository and enter the directory of SQLAlchemy examples

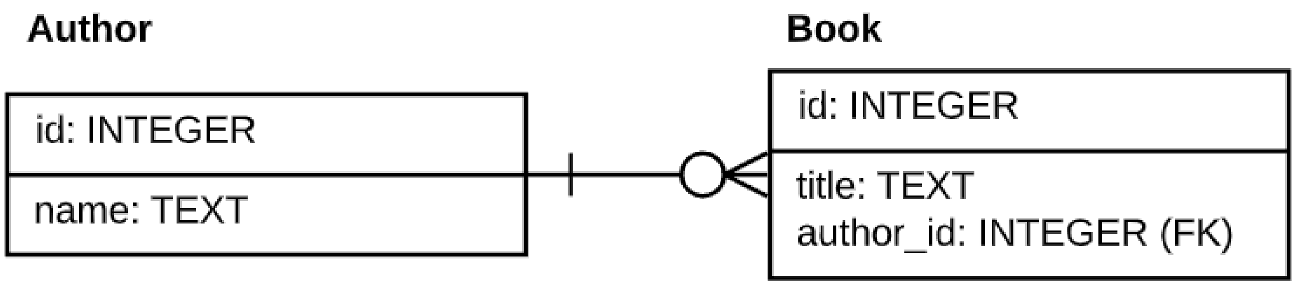
```
git clone https://www.ict.inaf.it/gitlab/odmc/orm_example.git
cd orm_example/sqlalchemy_example
```

ORM with SQLAlchemy: Example 1



- Engines https://docs.sqlalchemy.org/en/14/core/engines.html
- Declarative Base https://docs.sqlalchemy.org/en/14/orm/extensions/declarative/
- Session https://docs.sqlalchemy.org/en/14/orm/session.html
- Query https://docs.sqlalchemy.org/en/14/orm/query.html

ORM with SQLAlchemy: Example 2

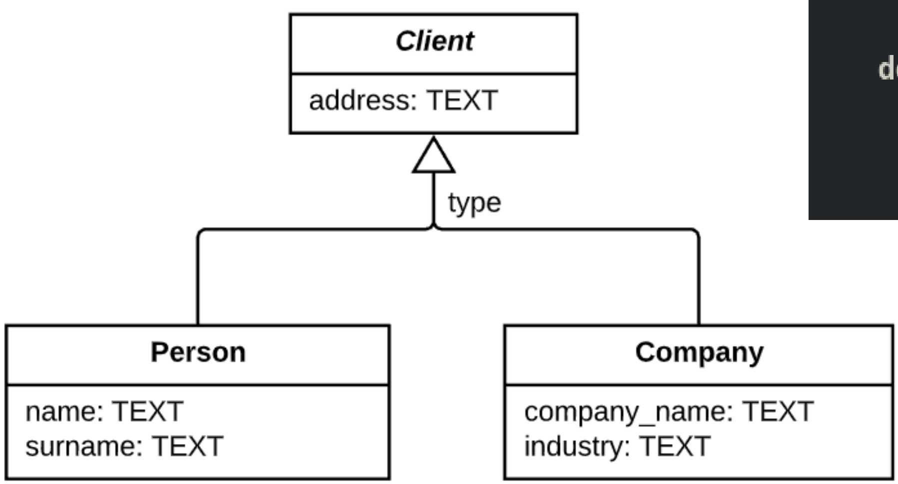


- Foreign keys in SQLite
  https://docs.sqlalchemy.org/en/14/dialects/sqlite.html#foreign-key-support
- Relationship
  https://docs.sqlalchemy.org/en/14/orm/basic_relationships.html

Inheritance in Python

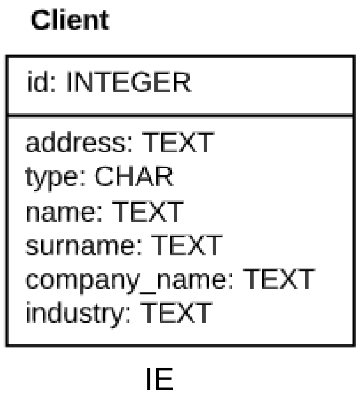
- This is a simple example of inheritance in UML and how can be implemented in Python

```python
class Client(object):
    """docstring for Client"""

    def __init__(self, address):
        super(Client, self).__init__()
        self.address = address


class Person(Client):
    """docstring for Person"""

    def __init__(self, name, surname, address):
        #super(Person, self).__init__(address)
        self.name = name
        self.surname = surname


class Company(Client):
    """docstring for Company"""

    def __init__(self, company_name, industry, address):
        super(Company, self).__init__(address)
        self.company_name = company_name
        self.industry = industry
```



UML

Inheritance in a Relational Database

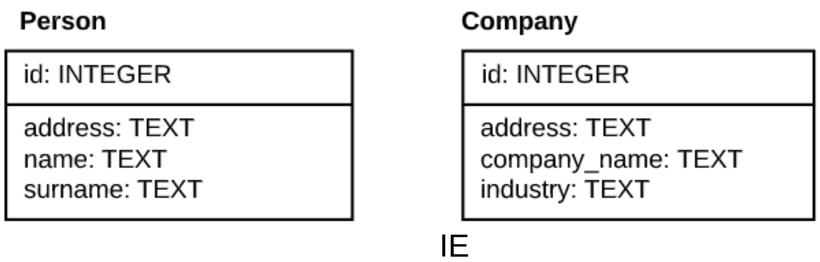


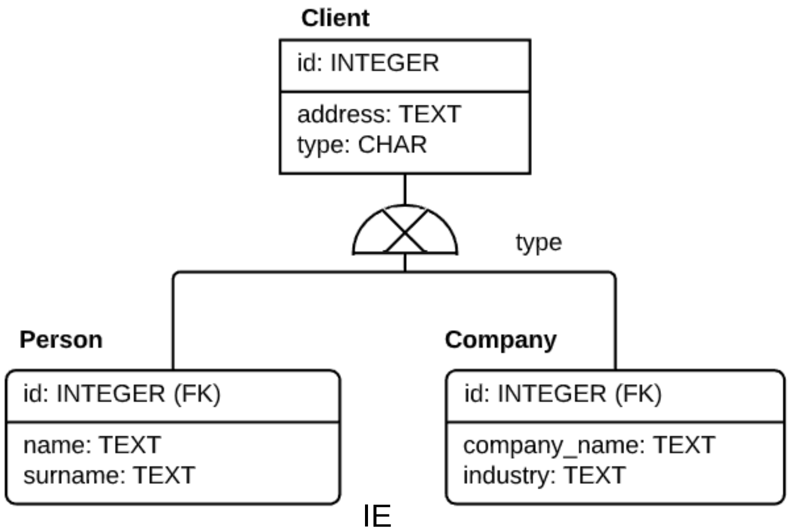
Single table inheritance

- Unique ID
- No JOIN necessary
- Many NULL attributes

Concrete table inheritance

- Not unique ID
- No JOIN necessary
- No NULL attributes

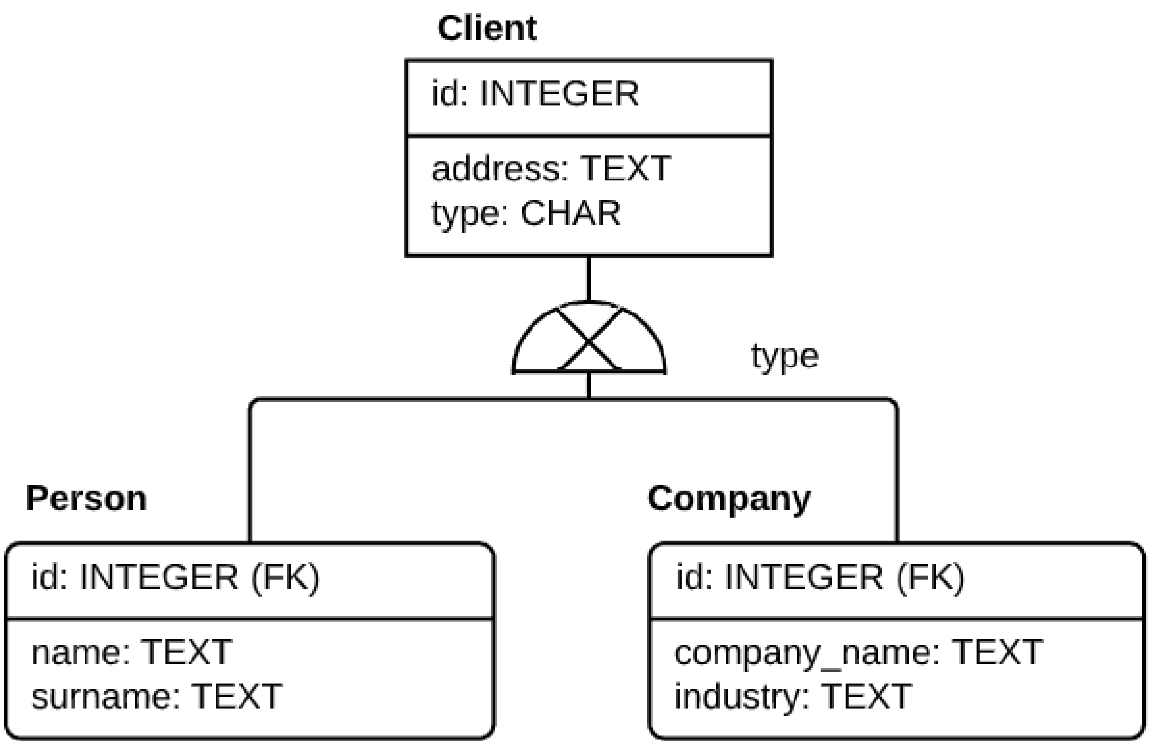




Joined table inheritance

- Unique ID
- JOIN necessary
- No NULL attributes

ORM with SQLAlchemy: Example 3



- Inheritance https://docs.sqlalchemy.org/en/14/orm/inheritance.html