

Technical documentation

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1 Lumen Geoguesser

1.1 Notices:

Although you might be reading this documentation in the form of a PDF file, **we strongly recommend that you open the `README.md` file in a markdown editor** (GitHub, VSCode, PyCharm, IDE...). As for the API documentation, after setting up the environment, we recommend you run the server with the `python3 src/app/main.py` command after which you can inspect API endpoints in a browser (and execute them too!). Essentially, the technical documentation PDF is rendered from the `README.md` markdown file and concatenated with the PDF API documentation.

A few more notes:

- the documentation assumes you are located at the `.lumen-geoguesser` directory when running Python scripts
- all global variables are defined in `src/config.py` and `src/paths.py`
- other directories have their own `README.md` files which hopefully will come in handy
- you can run most python files with the `python3 program.py -h` command to get a sense of which arguments you can/must send and what the script actually does

1.2 Directory Structure

| Directory | Description |
|-------------------------|--------------------------------------------|
| <code>data</code> | dataset, csvs, country shapefiles |
| <code>docs</code> | documentation |
| <code>figures</code> | figures |
| <code>models</code> | model checkpoints, model metadata |
| <code>references</code> | research papers and competition guidelines |
| <code>reports</code> | model checkpoints and model metadata |
| <code>src</code> | python source code |

1.3 Setup

1.3.1 Virtual Environment

Create and populate the **virtual environment**. Simply put, the virtual environment allows you to install Python packages for this project only (which you can easily delete later). This way, we won't clutter your global Python packages.

Step 1: Execute the following command: - the command will initialize the `venv` if it doesn't exist yet

```
[ ! -d "venv" ] && (echo "Creating python3 virtual environment"; python3 -m venv venv)
. venv/bin/activate
pip install -r requirements.txt
```

1.3.2 Dataset Setup

This project allows for the usage multiple datasets, therefore, multiple dataset directories can usually be sent to `*.py` programs

Step 1: If needed, rename directory `data` (which contains uuid subdirectories) to `images` - The original dataset structure has a directory `data` (e.g `dataset_original_subset/data`) which contains subdirectories with uuids of locations (`dataset_original_subset/data/6bde8efe-a565-4f05-8c60-ae2ffb32ee9b`).

Dataset structure should look like this:

```
dataset_original_subset/
├── images
│   ├── 6bde8efe-a565-4f05-8c60-ae2ffb32ee9b
│   │   ├── 0.jpg
│   │   ├── 180.jpg
│   │   ├── 270.jpg
│   │   └── 90.jpg
│   ├── 6c0ed2ea-b31b-4cfd-9828-4aec22bc0b37
│   │   ├── 0.jpg
│   │   └── 180.jpg
│   └── ...
├── ...
└── data.csv
```

```
dataset_external_subset/
├── images
│   ├── e61b6e5f-db0d-4f57-bbe3-4d31f16c5bc3
│   │   ├── 0.jpg
│   │   └── 180.jpg
│   └── ...
├── ...
└── data.csv
```

Step 2: Setup datasets with `src/preprocess_setup_datasets.py` - Before running other scripts, you have to properly setup a new dataset structure using the `src/preprocess_setup_datasets.py` file. It's important to note that this file accepts multiple dataset directories as an argument and it will make sure to merge the datasets correctly. No changes will be done to your original directories.

```
python3 src/preprocess_setup_datasets.py -h
```

```
usage: preprocess_setup_datasets.py [-h] [--dataset-dirs dir [dir ...]] [--out-dir dir] [--copy-images] [--spacing SPACING]
```

optional arguments:

```
-h, --help            show this help message and exit
```

```
--dataset-dirs dir [dir ...]
```

Dataset root directories that will be transformed into a single dataset

```
--out-dir dir        Directory where the complete dataset will be placed
```

```
--copy-images        Copy images from dataset directories to the new complete directory.
```

You don't need to do this as later on you will be able to pass multiple dataset directories to var

```
--spacing SPACING
```

Spacing that will be used to create a grid of polygons.

Different spacings generate a different number of classes

```
0.7 spacing => ~31 classes
```

```
0.5 spacing => ~55 classes
```

```
0.4 spacing => ~75 classes
```

```
0.3 spacing => ~115 classes
```

Example of running the initial setup script:

```
python3 src/preprocess_setup_datasets.py --dataset-dirs data/dataset_original_subset data/dataset_external_subset --out-dir
```

`preprocess_setup_datasets.py` does all the necessary preprocessing. However, underneath the hood it calls other preprocessing scripts. What happens when you run this script?

1. a directory for the new (complete) dataset is created, images are copied if `--copy-images` flag was passed
 2. `preprocess_csv_concat.main()` is called, which concatenates multiple `data.csv` s into a single `data.csv`
 3. this new (complete) `data.csv` is enriched by `preprocess_csv_create_rich_static.main()`. Here, regions (future classes) and their information (centroids, crs centroids ...) are attached to each location. Enriched data is saved to a *Rich static CSV* file created called `data_rich_static__spacing_<float>_classes_<int>`.
 4. Directory `images` in all directories (including the `complete` one) will be split into `train`, `val` and `test` directories.
- Note: directory `images` won't be deleted.

New dataset structure:

```
dataset_complete_subset/
├─ data.csv
├─ images <= exists if the --copy-images flag was passed
└─ data_rich_static__spacing_0.5_classes_55.csv

dataset_original_subset/
├─ data.csv
├─ images
├─ test
│   └─ c4a74f0d-7f30-4966-9b92-f63279139d68
│       ├── 0.jpg
│       └─ 180.jpg
│   ...
├─ ...
├─ train
└─ val

dataset_external_subset/
├─ data.csv
├─ images
├─ test
├─ train
└─ val
```

1.4 Training

After you prepared that new dataset structure, you can start the *quick version* of training:

```
python3 src/train.py --dataset-dirs data/dataset_external_subset/ data/dataset_original_subset/ \
--csv-rich-static data/dataset_complete_subset/data_rich_static__spacing_0.7_classes_31.csv \
--quick
```

`--csv-rich-static` can be left out which forces the *Rich static CSV* creation during runtime (this will somewhat slow down the initial setup). You can perform the full training by removing the `--quick` flag. Some additional interesting arguments are listed below. Run the `python src/train.py -h` command to see all supported arguments.

```
--image-size
--num-workers
--lr
--dataset-dirs [dir1, dir2, ...]
--csv-rich-static
--unfreeze-blocks
--pretrained
--quick
```

```
--batch-size
--optimizer
--regression
```

Example of production training (in our case):

```
python3 src/train.py \
--accelerator gpu --devices 1 --num-workers 32 \
--dataset-dir data/raw/ data/external/ \
--csv-rich-static data/complete/data_huge_spacing_0.21_num_class_211.csv \
--batch-size 8 --image-size 224 --lr 0.00002 \
--unfreeze-at-epoch 1 --scheduler plateau
```

During the training, a few things will occur in the `reports/` directory:

1. `reports/train_*.txt` files will be created which log everything that's outputted to the standard output
2. subdirectory `reports/<model_name>` will be created in which:
 1. `data_runtime.csv` will be created, serves as backup
 2. `version/0` directory which contains:
 1. `hparams.yaml` : details of hyperparameters
 2. `events.out.tfevents*` : log file which tensorboard consumes
 3. `checkpoints` : the most important subdirectory, contains model checkpoints (trained models)

```
reports/<model_name>/
├── data_runtime.csv
├── version_0
│   ├── checkpoints
│   │   ├── mymodel_checkpoint1.ckpt
│   │   └── mymodel_checkpoint2.ckpt
│   ├── events.out.tfevents.*
│   └── hparams.yaml
```

1.5 Logs - Tensorboard

Tensorboard logging is enabled by default. To see training and validation logs, run the command bellow. Logs should be available in a browser at `http://localhost:6006/` . For more options, check `tensorboard -h` .

```
tensorboard --port 6006 --logdir reports/
```



1.6 Local Server

A local server is useful when you are trying to do inference on a trained model. The sever code and config live in the `src/app` directory.

Before running the sever, set the variable `MODEL_DIRECTORY` in `src/app/.env` to a directory which contains (or will contain) model checkpoints (`.ckpt`). Models outside of this directory can't be used for inference via endpoints. We recommend creating a new directory called `models` and copying model checkpoint files (e.g. `reports/<model_name>/version_0/checkpoints/mymodel.ckpt`) to this directory.

Step 1. copy model checkpoints to /models/

```
mkdir models
cp -r reports/<model_name>/version_0/checkpoints/* models/
```

Step 1.1. ensure that the `MODEL_DIRECTORY` variable is set in `src/app/.env` file:

```
cat src/app/.env

MODEL_DIRECTORY = "models" # relative to the lumen-geoguesser directory
MODEL_EXTENSION = ".ckpt"
PREDICT_BATCH_SIZE = 16
HOST = "localhost"
PORT = 8090
HOT_RELOAD = 0 # please don't enable hot reloading as it's unstable
```

Step 2. run the server:

```
python3 src/app/main.py
```

FastAPI 0.1.0 OAS3

/openapi.json

Before consuming the endpoints set the variable `MODEL_DIRECTORY` in `.env` to a directory that contains model checkpoints (.ckpt). Models outside of this directory can't be used for inference via endpoints.

Command for running the server:

```
(venv) username@pc:~/lumen-geoguesser$ python3 src/app/main.py
```

available models All available models from the `MODEL_DIRECTORY` directory defined in the `.env` file

GET `/models` Get Models

Endpoints used for predicting latitude and longitudes for given data. Curl example for multiple images:

predict

```
curl -i \
-F "images=@data/raw/images/train/e788b3d1-9d20-466c-9dee-97982f0f9a3b/0.jpg" \
-F "images=@data/raw/images/train/e788b3d1-9d20-466c-9dee-97982f0f9a3b/0.jpg" \
http://0.0.0.0:8090/model/Golf_76_haversine_0.0098_val_acc_0.47_val_loss_1.98_05-04-03-36-32/predict-images
```

POST `/model/{model_name}/predict-images` Predict Images

POST `/model/{model_name}/predict-cardinal-images` Predict Cardinal Images

POST `/model/{model_name}/predict-directory` Predict Dataset

Schemas

Body_predict_cardinal_images_model__model_name__predict_cardinal_images_post >

API Reference

FastAPI

API Version: 0.1.0

Before consuming the endpoints set the variable `MODEL_DIRECTORY` in `.env` to a directory that contains model checkpoints (`.ckpt`). Models outside of this directory can't be used for inference via endpoints.

Command for running the server:

```
(venv) username@pc:~/lumen-geoguesser$ python3 src/app/main.py
```

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API

1. AVAILABLE MODELS

All available models from the MODEL_DIRECTORY directory defined in the .env file

1.1 GET /models

Get Models

Returns names of all available models on the server. You must use model names for all POST request predictions. Model name is a stem of the model checkpoint, e.g. model with filename my_model.ckpt has the name my_model. Models are fetched from the directory MODEL_DIRECTORY which is defined in the .env file. Only models with the extension MODEL_EXTENSION are fetched. Model names will be returned instead of the model filenames.

REQUEST

No request parameters

RESPONSE

STATUS CODE - 200: Successful Response

RESPONSE MODEL - application/json

2. PREDICT

Endpoints used for predicting latitude and longitudes for given data. Curl example for multiple images:

```
curl -i -F "images=@data/raw/images/train/e788b3d1-9d20-466c-9dee-97982f0f9a3b/0.jpg" -F "images=@data/raw/images/train/e788b3d1-9d20-466c-9dee-97982f0f9a3b/0.jpg" \
http://0.0.0.0:8090/model/
Golf_76__haversine_0.0098__val_acc_0.47__val_loss_1.98__05-04-03-36-32/predict-images
```

2.1 POST /model/{model_name}/predict-images

Predict Images

Infers latitude and longitude for multiple images. If you have a group of images where each image represents one cardinal direction (north, east, south, and west) ("0.jpg", ... , "270.jpg") you should use the `/model/{model_name}/predict-cardinal-images` endpoint

REQUEST

PATH PARAMETERS

| NAME | TYPE | DESCRIPTION |
|-------------|--------|-------------|
| *model_name | string | |

FORM DATA PARAMETERS

| NAME | TYPE | DESCRIPTION |
|--------|-----------------|-------------|
| images | array of string | |

RESPONSE

STATUS CODE - 200: Successful Response

RESPONSE MODEL - application/json

| NAME | TYPE | DESCRIPTION |
|--------------------------------------|--------|-------------|
| ARRAY OF OBJECT WITH BELOW STRUCTURE | | |
| latitude* | number | |
| longitude* | number | |

STATUS CODE - 422: Validation Error

RESPONSE MODEL - application/json

| NAME | TYPE | DESCRIPTION |
|-----------------------------|---------|-------------|
| OBJECT WITH BELOW STRUCTURE | | |
| detail | array | |
| loc* | array | |
| ANY:OF | object | |
| prop0 | string | |
| prop1 | integer | |

| NAME | TYPE | DESCRIPTION |
|-------|--------|-------------|
| msg* | string | |
| type* | string | |

2.2 POST /model/{model_name}/predict-directory

Predict Dataset

Infers latitude and longitude for all images in the directory (dataset_directory_path) which contains subdirectories (uuid) with images for each cardinal direction. This structure is the same as the structure of the original dataset. Exactly 4 images must be sent per subdirectory and each image filename must match image's cardinal direction ("0.jpg", "90.jpg", "180.jpg", "270.jpg"). E.g northen image should be named "0.jpg". If csv_filename is provided, results will also be saved to a .csv file.

REQUEST

PATH PARAMETERS

| NAME | TYPE | DESCRIPTION |
|-------------|--------|-------------|
| *model_name | string | |

REQUEST BODY - application/json

| NAME | TYPE | DESCRIPTION |
|-------------------------|--------|-------------|
| csv_filename | string | |
| dataset_directory_path* | string | |

RESPONSE

STATUS CODE - 200: Successful Response

RESPONSE MODEL - application/json

| NAME | TYPE | DESCRIPTION |
|--------------------------------------|--------|-------------|
| ARRAY OF OBJECT WITH BELOW STRUCTURE | | |
| uuid* | string | |
| latitude* | number | |
| longitude* | number | |

STATUS CODE - 422: Validation Error

RESPONSE MODEL - application/json

| NAME | TYPE | DESCRIPTION |
|-----------------------------|---------|-------------|
| OBJECT WITH BELOW STRUCTURE | | |
| detail | array | |
| loc* | array | |
| ANY:OF | object | |
| prop0 | string | |
| prop1 | integer | |
| msg* | string | |
| type* | string | |

2.3 POST /model/{model_name}/predict-cardinal-images

Predict Cardinal Images

Infers latitude and longitude for a single location which is defined by exactly 4 images, each for one cardinal direction. Exactly 4 images must be sent and each image filename must match image's cardinal direction ("0.jpg", "90.jpg", "180.jpg", "270.jpg"). E.g northen image should be named "0.jpg". This structure is the same as the structure of the original dataset.

REQUEST

PATH PARAMETERS

| NAME | TYPE | DESCRIPTION |
|-------------|--------|-------------|
| *model_name | string | |

FORM DATA PARAMETERS

| NAME | TYPE | DESCRIPTION |
|--------|-----------------|-------------|
| images | array of string | |

RESPONSE

STATUS CODE - 200: Successful Response

RESPONSE MODEL - application/json

| NAME | TYPE | DESCRIPTION |
|--------------------------------------|--------|-------------|
| ARRAY OF OBJECT WITH BELOW STRUCTURE | | |
| latitude* | number | |
| longitude* | number | |

STATUS CODE - 422: Validation Error

RESPONSE MODEL - application/json

| NAME | TYPE | DESCRIPTION |
|-----------------------------|---------|-------------|
| OBJECT WITH BELOW STRUCTURE | | |
| detail | array | |
| loc* | array | |
| ANY:OF | object | |
| prop0 | string | |
| prop1 | integer | |
| msg* | string | |
| type* | string | |