LDP-Shuffle-Parameters

May 21, 2025

1 VLDP - Geolife & Smart Meter dataset

1.0.1 Dataset preprocessing and computing parameters

In this notebook, we show how we created the datasets as used in the paper from the original open datasets. Moreover, we compute the value of the γ parameter for our use case evaluations.

1.0.2 Privacy Parameters

Before going into the specifics of the use cases, we first define the randomizer algorithms for real values and histograms (following the paper).

The code below also determines the privacy amplification we get through shuffling, for some arbitrarily chosen parameters. Give the target overall ϵ and δ and the number of participants n, it gives the ϵ_0 needed by the local randomizer.

We make use of the shuffleddp repository [Balle'19] to determine the bounds of our LDP randomizers and implement them in Python.

Let's first import all the required packages.

[Balle'19] Balle, B., Bell, J., Gascón, A. and Nissim, K., 2019. The privacy blanket of the shuffle model. In Advances in Cryptology–CRYPTO 2019: 39th Annual International Cryptology Conference, Santa Barbara, CA, USA, August 18–22, 2019, Proceedings, Part II 39 (pp. 638-667). Springer International Publishing.

[15]:
```
import numpy as np
import csv
import os
import pandas as pd
import itertools
import kagglehub
from urllib.request import urlretrieve, urlcleanup
from geopy.geocoders import Nominatim
from geopy.exc import GeocoderTimedOut
from zipfile import ZipFile
import datetime
from shuffleddp.mechanisms import *
from shuffleddp.amplification_bounds import *
```

1.0.3 Algorithm for Real Values

Given $x \in [0, 1]$, the following algorithm calculates the sum of i such values by first encoding them with precision k and then applying the LDP and the Analyzer algorithm given in Section 4.1 of [Balle'19].

[16]:
```
# Target (eps, delta)-guarantee required
eps = 0.1
delta = 1e-6

n = 5000  # number of participants
k = 100  # precision level
rrk = RRMechanism(k=k + 1)  # we have the range of {0, 1, ..., k + 1}

bound_types = [Hoeffding, BennettExact]
all_bounds = []
for B in bound_types:
    all_bounds.append(B(rrk))

print(f"Epsilon: {eps}", eps)
print(f"Delta: {delta}")
print(f"Number of participants: {n}")
bounds = {b.get_name(): b.get_eps0(eps, n, delta) for b in all_bounds}
print(f"Bounds: {bounds}")

gamma = rrk.get_gamma()[0]
print(f"Gamma: {gamma}")


# The first part of the randomizer (float encoding as int)
def encode(x, k):
    p = x * k - np.floor(x * k)
    x_enc = np.floor(x * k) + np.random.binomial(1, p)
    return x_enc


# second part of the randomizer (randomized response)
def RRMech(x, gamma, k):
    if not np.random.binomial(1, gamma):
        return x
    else:
        return np.random.randint(k + 1)


# apply float encoding to random inputs (as example)
true_vals = np.random.rand(1, n)
encode_v = np.vectorize(encode)
enc_true_vals = encode_v(true_vals, k)
```

```
# apply randomized response
RRMech_v = np.vectorize(RRMech)
received_vals = RRMech_v(enc_true_vals[0], gamma, k)

# compute outpus
sample_sum = sum(received_vals)
estimate = (sample_sum / k - gamma * n / 2) / (1 - gamma)
print(f"Estimate: {estimate}")
print(f"Actual: {sum(true_vals[0])}")
print(f"Received sum divided by k: {sample_sum / k}")
```

```
Epsilon: 0.1 0.1
Delta: 1e-06
Number of participants: 5000
Bounds: {'Hoeffding, RR-101': 0.9959842619145971, 'Bennett, RR-101':
2.5523496569511277}
Gamma: 0.89509463046459
Estimate: 2524.307621347632
Actual: 2514.664336357696
Received sum divided by k: 2502.55
```

1.0.4 Algorithm for Histogram

Given $x \in [k]$, the following algorithm calculates the histogram of values by applying the LDP algorithm given in Section 3.1 of [Balle'19]. Note that the values are already integers.

[17]:
```
# Target (eps, delta)-guarantee required
eps = 0.2
delta = 1e-6

n = 1000  # number of participants
k = 100  # precision level
rrk = RRMechanism(k=k)  # we have the range of {0, 1, ..., k}

bound_types = [Hoeffding, BennettExact]
all_bounds = []
for B in bound_types:
    all_bounds.append(B(rrk))

print(f"Epsilon: {eps}", eps)
print(f"Delta: {delta}")
print(f"Number of participants: {n}")
bounds = {b.get_name(): b.get_eps0(eps, n, delta) for b in all_bounds}
print(f"Bounds: {bounds}")

gamma = rrk.get_gamma()[0]
print(f"Gamma: {gamma}")
```

```python
# the randomizer algorithm (randomized response)
def RRMechHist(x, gamma, k):
    b = np.random.binomial(1, gamma)
    if not b:
        return x
    else:
        return np.random.randint(1, k + 1)


# generate random inputs
true_vals = np.random.choice(np.arange(1, k + 1), n)

# apply randomizer
RRMechHist_v = np.vectorize(RRMechHist)
received_vals = RRMechHist_v(true_vals, gamma, k)

# compute outputs
_unique, true_counts = np.unique(true_vals, return_counts=True)
_unique, est_counts = np.unique(received_vals, return_counts=True)
print(f"Estimate: {est_counts}")
print(f"Actual: {true_counts}")
```

```
Epsilon: 0.2 0.2
Delta: 1e-06
Number of participants: 1000
Bounds: {'Hoeffding, RR-100': 0.9026877389112389, 'Bennett, RR-100':
2.3257610671469986}
Gamma: 0.9154619731616345
Estimate: [15 13 13 13 12  5 10 10 13  8  7 14  8 11  5 10  9 13  9  6  6 14  3
10
 11 12 11 13  8 10 18  7 17 16  8  8  9 10  8 15 11  8 14 13 10  5  9  7
 10 11  9  6  9  9  7 11 15  4  9  5 10 12  8  6  9 12  3 12 11 10  5 12
 11 11 12 12 11 11  8  5  7  8 11  9  6 14 13  9  2  9 17 12  9 19 11 15
 13  6 11  8]
Actual: [10 17 11 11 13 11 17  8  8 12  6  7 14  8  9 10 14 10  9  8 11 13  9 11
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 10 19  7  4 10  8 11 12  8 18  8  7 13  8 15 12  8 15 11 10  5 13  8  8
  9  6 12  9]
```

1.0.5 Smart Meter Data (Use Case 1)

In this Section we describe the dataset preparation and show how we determine the bounds/run a DP example on this dataset.

The dataset is an application of the mechanism for summing up real numbers (from which we can

obtain the average as well), i.e., Algorithms for Real Values, as mentioned above. The dataset is taken from: https://www.kaggle.com/datasets/jeanmidev/smart-meters-in-london. In particular, the dataset `daily_dataset.csv` is used.

Note: to download the original dataset from Kaggle using the code below, one MIGHT (often it is not needed) has to make an account and set up a token following the "Installation" and "Authentication" sections on https://www.kaggle.com/docs/api. One can then uncomment the specified line below and use the information from the token to login to the Kaggle API.

[18]:
```
# NOTE: IF KAGGLE API KEY IS NEEDED UNCOMMENT BELOW
# kagglehub.login()

dataset_path = kagglehub.dataset_download("jeanmidev/smart-meters-in-london")
dataset = "daily_dataset.csv"
df = pd.read_csv(os.path.join(dataset_path, dataset))
```

[19]:
```
# inspect dataset
df.head
```

[19]:
```
<bound method NDFrame.head of              LCLid         day  energy_median
energy_mean  energy_max  \
0         MAC000131  2011-12-15         0.4850     0.432045       0.868
1         MAC000131  2011-12-16         0.1415     0.296167       1.116
2         MAC000131  2011-12-17         0.1015     0.189812       0.685
3         MAC000131  2011-12-18         0.1140     0.218979       0.676
4         MAC000131  2011-12-19         0.1910     0.325979       0.788
…               …           …              …            …           …
3510428   MAC004977  2014-02-24         0.0950     0.118458       0.580
3510429   MAC004977  2014-02-25         0.0675     0.084208       0.176
3510430   MAC004977  2014-02-26         0.1080     0.120500       0.282
3510431   MAC004977  2014-02-27         0.0720     0.114062       0.431
3510432   MAC004977  2014-02-28         0.0970     0.097000       0.097

          energy_count  energy_std  energy_sum  energy_min
0                   22    0.239146       9.505       0.072
1                   48    0.281471      14.216       0.031
2                   48    0.188405       9.111       0.064
3                   48    0.202919      10.511       0.065
4                   48    0.259205      15.647       0.066
…                  …           …           …           …
3510428             48    0.093814       5.686       0.052
3510429             48    0.037107       4.042       0.046
3510430             48    0.069332       5.784       0.046
3510431             48    0.094482       5.475       0.047
3510432              1         NaN       0.097       0.097

[3510433 rows x 9 columns]>
```

1.0.6 DP Parameters and Example Run (Use Case 1)

[20]:
```
# maximum possible value of energy -- we will normalize using this
max_energy = df["energy_mean"].max()
print("Max energy:", max_energy)

# Total number of households
households = df["LCLid"].unique()
n = len(households)

eps = 0.2  # Target (eps, delta)-guarantee required
delta = 1e-6
k = 10  # precision level
rrk = RRMechanism(k=k + 1)

bound_types = [Hoeffding, BennettExact]
all_bounds = []
for B in bound_types:
    all_bounds.append(B(rrk))

print(f"Epsilon: {eps}", eps)
print(f"Delta: {delta}")
print(f"Number of participants: {n}")
bounds = {b.get_name(): b.get_eps0(eps, n, delta) for b in all_bounds}
print(f"Bounds: {bounds}")

gamma = rrk.get_gamma()[0]
print(f"Gamma: {gamma}")

num_days = int(1 / eps)  # we will run the mechanism a total of 1/eps times

print("k:", k)
print("n:", n)
print("Number of days:", num_days)
print("eps0:", rrk.get_eps0())
print("================\n")

last_day = "2014-02-25"
cur_date = datetime.datetime.strptime(last_day, '%Y-%m-%d').date()
delta = datetime.timedelta(days=1)


# Normalize energy values within [0, 1]
def normalizeVals(vals):
    for i in range(len(vals)):
        vals[i] = vals[i] / (max_energy)
    return vals
```

```
# also store data for writing to csv
energy_vals_for_csv = []

# do an example DP run on this data and simultaneously parse the data
for i in range(num_days):
    day = cur_date.strftime('%Y-%m-%d')
    cur_date -= delta
    df0 = df[['LCLid', 'day', 'energy_mean']]
    df1 = df0[df0['day'] == day]
    energy_vals = [0.0 for i in range(len(households))]
    for j in range(len(households)):
        energy = df1.loc[df1['LCLid'] == households[j], 'energy_mean'].values
        if energy.size != 0:
            energy_vals[j] = energy[0]
    energy_vals = normalizeVals(energy_vals)
    true_vals = energy_vals
    encode_v = np.vectorize(encode)
    enc_true_vals = encode_v(true_vals, k)

    RRMech_v = np.vectorize(RRMech)
    received_vals = RRMech_v(enc_true_vals, gamma, k)

    sample_sum = sum(received_vals)
    # This is the de-biasing step in Algorithm 3 of [Balle'19]
    estimate = (sample_sum / k - gamma * n / 2) / (1 - gamma)
    print(f"Run {i + 1}:")
    print(f"Estimate: {estimate / n}")
    print(f"Actual: {sum(true_vals) / n}")
    print("==================\n")
    energy_vals_for_csv.append(energy_vals)
```

```
Max energy: 6.928250020833329
Epsilon: 0.2 0.2
Delta: 1e-06
Number of participants: 5566
Bounds: {'Hoeffding, RR-11': 1.6116776981605088, 'Bennett, RR-11':
2.48270496095323}
Gamma: 0.5006005204469995
k: 10
n: 5566
Number of days: 5
eps0: 2.482704960952729
================

Run 1:
```

```
Estimate: 0.028539038174632547
Actual: 0.027832181900990727
==================

Run 2:
Estimate: 0.0018451019919219146
Actual: 0.028096308785484303
==================

Run 3:
Estimate: 0.020120734850165824
Actual: 0.031060984630618366
==================

Run 4:
Estimate: 0.030481723557201818
Actual: 0.029218913551385617
==================

Run 5:
Estimate: 0.013717068218733914
Actual: 0.028447346459788043
==================
```

1.0.7 Writing Extracted Smart Meter Data

The following extracts only relevant information into a CSV file. Namely the average energy consumption per household over the days used in the algorithm.

[21]:
```
# Write the normalized energy values into a csv file
with open("energy_data.csv", "w", newline='') as f:
    wr = csv.writer(f, delimiter=",")
    header_row = ["household", "day", "average energy"]
    wr.writerow(header_row)
    for i in range(len(energy_vals_for_csv)):
        vals = energy_vals_for_csv[i]
        for j in range(len(vals)):
            row = [j, i, vals[j]]
            wr.writerow(row)
```

1.0.8 Geolife GPS Trajectory Dataset (Use Case 2)

In this Section we describe the dataset preparation and show how we determine the bounds/run a DP example on this dataset.

Taken from https://www.microsoft.com/en-us/research/publication/geolife-gps-trajectory-dataset-user-guide/. The following extracts the first longitude, latitude entry on a given date from files corresponding to all users. Not all users have date for each day.

First we download and unpack the original data. (Note: This can take up to 10-15 minutes, since it's a lot of data to unpack)

[22]:
```
zip_path, _headers = urlretrieve(
    "https://download.microsoft.com/download/F/4/8/
 ↪F4894AA5-FDBC-481E-9285-D5F8C4C4F039/Geolife%20Trajectories%201.3.zip")

with ZipFile(zip_path, 'r') as zip_file:
    zip_file.extractall(os.getcwd())

# remove downloaded tmp file
urlcleanup()
```

1.0.9 First Latitude, Longitude Reading from All Users One Day at a Time

We only need a subselection of the data, so we do that as follows. This code takes the first lat long from each user's file of the first 5 days.

[23]:
```
work_dir = "Geolife Trajectories 1.3/Data"
users = ["{:03d}".format(i) for i in range(182)]
sub_dir = "Trajectory"

latLongs = []
days = 5

for user in users:
    cur_dir = os.path.join(work_dir, user, sub_dir)
    files = sorted([filename for filename in os.listdir(cur_dir)])
    for day in range(days):
        if day < len(files):
            cur_file = os.path.join(cur_dir, files[day])
            with open(cur_file, 'r') as f:
                reader = csv.reader(f, delimiter='|')
                rows = list(reader)

            flat_rows = itertools.chain.from_iterable(rows)
            list_rows = [i.strip().split(',') for i in flat_rows]

            df = pd.DataFrame(list_rows[6:])  # first 6 lines are useless

            lat = df.iloc[0][0]
            long = df.iloc[0][1]
            latLongs.append([user, day, lat, long])

print(f"Number of records: {len(latLongs)}")
print("Head:")
print(latLongs[:6])
```

```
Number of records: 851
Head:
[['000', 0, '39.984702', '116.318417'], ['000', 1, '40.008304', '116.319876'],
['000', 2, '39.907414', '116.370017'], ['000', 3, '39.994622', '116.326757'],
['000', 4, '40.01229', '116.297072'], ['001', 0, '39.984094', '116.319236']]
```

1.0.10 Calling the Reverse Geo API

Next we transform the latitudes and longitudes found in the data into postcodes using a geodata lookup.

NOTE: please specify the use agent on line 7, for example use your e-mail or the name of the application. This is necessary to follow the conditions of the API used.

[24]:
```python
# TODO: set USER AGENT
# initialize Nominatim API
geolocator = Nominatim(user_agent="PLEASE SPECIFY")

for idx, data in enumerate(latLongs):
    print(f"{idx + 1}/{len(latLongs)}")
    lat = data[2]
    long = data[3]
    try:
        location = geolocator.reverse(lat + "," + long, language='en')
        address = location.raw['address']
        if 'postcode' in address:
            data.append(address['postcode'])
        else:
            data.append("None")
    except GeocoderTimedOut as e:
        print("Error: geocode failed on input %s" % (lat + "," + long))
        data.append("TimeOut")
print("done")
```

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```
---------------------------------------------------------------------------
TimeoutError                              Traceback (most recent call last)
File ~/src/reserch/VLDP/.venv/lib/python3.11/site-packages/urllib3/
 ↪connectionpool.py:534, in HTTPConnectionPool._make_request(self, conn, method␣
 ↪url, body, headers, retries, timeout, chunked, response_conn, preload_content␣
 ↪decode_content, enforce_content_length)
    533 try:
--> 534     response = conn.getresponse()
    535 except (BaseSSLError, OSError) as e:

File ~/src/reserch/VLDP/.venv/lib/python3.11/site-packages/urllib3/connection.py:
 ↪516, in HTTPConnection.getresponse(self)
    515 # Get the response from http.client.HTTPConnection
--> 516 httplib_response = super().getresponse()
    518 try:

File ~/.pyenv/versions/3.11.8/lib/python3.11/http/client.py:1390, in␣
 ↪HTTPConnection.getresponse(self)
   1389 try:
-> 1390     response.begin()
   1391 except ConnectionError:

File ~/.pyenv/versions/3.11.8/lib/python3.11/http/client.py:325, in HTTPRespons.
 ↪begin(self)
    324 while True:
--> 325     version, status, reason = self._read_status()
    326     if status != CONTINUE:

File ~/.pyenv/versions/3.11.8/lib/python3.11/http/client.py:286, in HTTPRespons.
 ↪_read_status(self)
    285 def _read_status(self):
--> 286     line = str(self.fp.readline(_MAXLINE + 1), "iso-8859-1")
    287     if len(line) > _MAXLINE:
```

```
File ~/.pyenv/versions/3.11.8/lib/python3.11/socket.py:706, in SocketIO.
 ↪readinto(self, b)
    705 try:
--> 706     return self._sock.recv_into(b)
    707 except timeout:

File ~/.pyenv/versions/3.11.8/lib/python3.11/ssl.py:1314, in SSLSocket.
 ↪recv_into(self, buffer, nbytes, flags)
   1311         raise ValueError(
   1312           "non-zero flags not allowed in calls to recv_into() on %s" %
   1313           self.__class__)
-> 1314     return self.read(nbytes, buffer)
   1315 else:

File ~/.pyenv/versions/3.11.8/lib/python3.11/ssl.py:1166, in SSLSocket.
 ↪read(self, len, buffer)
   1165 if buffer is not None:
-> 1166     return self._sslobj.read(len, buffer)
   1167 else:

TimeoutError: The read operation timed out

The above exception was the direct cause of the following exception:

ReadTimeoutError                          Traceback (most recent call last)
File ~/src/reserch/VLDP/.venv/lib/python3.11/site-packages/urllib3/
 ↪connectionpool.py:787, in HTTPConnectionPool.urlopen(self, method, url, body,
 ↪headers, retries, redirect, assert_same_host, timeout, pool_timeout,␣
 ↪release_conn, chunked, body_pos, preload_content, decode_content,␣
 ↪**response_kw)
    786 # Make the request on the HTTPConnection object
--> 787 response = self._make_request(
    788     conn,
    789     method,
    790     url,
    791     timeout=timeout_obj,
    792     body=body,
    793     headers=headers,
    794     chunked=chunked,
    795     retries=retries,
    796     response_conn=response_conn,
    797     preload_content=preload_content,
    798     decode_content=decode_content,
    799     **response_kw,
    800 )
    802 # Everything went great!
```

```
File ~/src/reserch/VLDP/.venv/lib/python3.11/site-packages/urllib3/
 ↪connectionpool.py:536, in HTTPConnectionPool._make_request(self, conn, method␣
 ↪url, body, headers, retries, timeout, chunked, response_conn, preload_content␣
 ↪decode_content, enforce_content_length)
    535 except (BaseSSLError, OSError) as e:
--> 536     self._raise_timeout(err=e, url=url, timeout_value=read_timeout)
    537     raise

File ~/src/reserch/VLDP/.venv/lib/python3.11/site-packages/urllib3/
 ↪connectionpool.py:367, in HTTPConnectionPool._raise_timeout(self, err, url,␣
 ↪timeout_value)
    366 if isinstance(err, SocketTimeout):
--> 367     raise ReadTimeoutError(
    368         self, url, f"Read timed out. (read timeout={timeout_value})"
    369     ) from err
    371 # See the above comment about EAGAIN in Python 3.

ReadTimeoutError: HTTPSConnectionPool(host='nominatim.openstreetmap.org',␣
 ↪port=443): Read timed out. (read timeout=1)

The above exception was the direct cause of the following exception:

MaxRetryError                             Traceback (most recent call last)
File ~/src/reserch/VLDP/.venv/lib/python3.11/site-packages/requests/adapters.py
 ↪667, in HTTPAdapter.send(self, request, stream, timeout, verify, cert, proxie␣)
    666 try:
--> 667     resp = conn.urlopen(
    668         method=request.method,
    669         url=url,
    670         body=request.body,
    671         headers=request.headers,
    672         redirect=False,
    673         assert_same_host=False,
    674         preload_content=False,
    675         decode_content=False,
    676         retries=self.max_retries,
    677         timeout=timeout,
    678         chunked=chunked,
    679     )
    681 except (ProtocolError, OSError) as err:

File ~/src/reserch/VLDP/.venv/lib/python3.11/site-packages/urllib3/
 ↪connectionpool.py:871, in HTTPConnectionPool.urlopen(self, method, url, body,␣
 ↪headers, retries, redirect, assert_same_host, timeout, pool_timeout,␣
 ↪release_conn, chunked, body_pos, preload_content, decode_content,␣
 ↪**response_kw)
    868     log.warning(
    869         "Retrying (%r) after connection broken by '%r': %s", retries,␣
 ↪err, url
```

```
    870     )
--> 871     return self.urlopen(
    872         method,
    873         url,
    874         body,
    875         headers,
    876         retries,
    877         redirect,
    878         assert_same_host,
    879         timeout=timeout,
    880         pool_timeout=pool_timeout,
    881         release_conn=release_conn,
    882         chunked=chunked,
    883         body_pos=body_pos,
    884         preload_content=preload_content,
    885         decode_content=decode_content,
    886         **response_kw,
    887     )
    889 # Handle redirect?

File ~/src/reserch/VLDP/.venv/lib/python3.11/site-packages/urllib3/
 ↪connectionpool.py:871, in HTTPConnectionPool.urlopen(self, method, url, body,
 ↪headers, retries, redirect, assert_same_host, timeout, pool_timeout,␣
 ↪release_conn, chunked, body_pos, preload_content, decode_content,␣
 ↪**response_kw)
    868     log.warning(
    869         "Retrying (%r) after connection broken by '%r': %s", retries,␣
 ↪err, url
    870     )
--> 871     return self.urlopen(
    872         method,
    873         url,
    874         body,
    875         headers,
    876         retries,
    877         redirect,
    878         assert_same_host,
    879         timeout=timeout,
    880         pool_timeout=pool_timeout,
    881         release_conn=release_conn,
    882         chunked=chunked,
    883         body_pos=body_pos,
    884         preload_content=preload_content,
    885         decode_content=decode_content,
    886         **response_kw,
    887     )
    889 # Handle redirect?
```

```
File ~/src/reserch/VLDP/.venv/lib/python3.11/site-packages/urllib3/
 ↪connectionpool.py:841, in HTTPConnectionPool.urlopen(self, method, url, body,␣
 ↪headers, retries, redirect, assert_same_host, timeout, pool_timeout,␣
 ↪release_conn, chunked, body_pos, preload_content, decode_content,␣
 ↪**response_kw)
    839     new_e = ProtocolError("Connection aborted.", new_e)
--> 841 retries = retries.increment(
    842     method, url, error=new_e, _pool=self, _stacktrace=sys.exc_info()[2]
    843 )
    844 retries.sleep()

File ~/src/reserch/VLDP/.venv/lib/python3.11/site-packages/urllib3/util/retry.py:
 ↪519, in Retry.increment(self, method, url, response, error, _pool, _stacktrace)
    518     reason = error or ResponseError(cause)
--> 519     raise MaxRetryError(_pool, url, reason) from reason  # type:␣
 ↪ignore[arg-type]
    521 log.debug("Incremented Retry for (url='%s'): %r", url, new_retry)

MaxRetryError: HTTPSConnectionPool(host='nominatim.openstreetmap.org', port=443):
 ↪ Max retries exceeded with url: /reverse?lat=39.975061&lon=116.
 ↪329201&format=json&accept-language=en&addressdetails=1 (Caused by␣
 ↪ReadTimeoutError("HTTPSConnectionPool(host='nominatim.openstreetmap.org',␣
 ↪port=443): Read timed out. (read timeout=1)"))

During handling of the above exception, another exception occurred:

ConnectionError                           Traceback (most recent call last)
File ~/src/reserch/VLDP/.venv/lib/python3.11/site-packages/geopy/adapters.py:
 ↪482, in RequestsAdapter._request(self, url, timeout, headers)
    481 try:
--> 482     resp = self.session.get(url, timeout=timeout, headers=headers)
    483 except Exception as error:

File ~/src/reserch/VLDP/.venv/lib/python3.11/site-packages/requests/sessions.py
 ↪602, in Session.get(self, url, **kwargs)
    601 kwargs.setdefault("allow_redirects", True)
--> 602 return self.request(      , url, **kwargs)

File ~/src/reserch/VLDP/.venv/lib/python3.11/site-packages/requests/sessions.py
 ↪589, in Session.request(self, method, url, params, data, headers, cookies,␣
 ↪files, auth, timeout, allow_redirects, proxies, hooks, stream, verify, cert,␣
 ↪json)
    588 send_kwargs.update(settings)
--> 589 resp = self.send(prep, **send_kwargs)
    591 return resp

File ~/src/reserch/VLDP/.venv/lib/python3.11/site-packages/requests/sessions.py
 ↪703, in Session.send(self, request, **kwargs)
    702 # Send the request
--> 703 r = adapter.send(request, **kwargs)
```

```
    705 # Total elapsed time of the request (approximately)

File ~/src/reserch/VLDP/.venv/lib/python3.11/site-packages/requests/adapters.py
 ↪700, in HTTPAdapter.send(self, request, stream, timeout, verify, cert, proxie
    698         raise SSLError(e, request=request)
--> 700     raise ConnectionError(e, request=request)
    702 except ClosedPoolError as e:

ConnectionError: HTTPSConnectionPool(host='nominatim.openstreetmap.org',␣
 ↪port=443): Max retries exceeded with url: /reverse?lat=39.975061&lon=116.
 ↪329201&format=json&accept-language=en&addressdetails=1 (Caused by␣
 ↪ReadTimeoutError("HTTPSConnectionPool(host='nominatim.openstreetmap.org',␣
 ↪port=443): Read timed out. (read timeout=1)"))

During handling of the above exception, another exception occurred:

GeocoderUnavailable                       Traceback (most recent call last)
Cell In[24], line 10
      8 long = data[3]
      9 try:
---> 10     location = geolocator.reverse(lat +     + long, language=    )
     11     address = location.raw['address']
     12     if 'postcode' in address:

File ~/src/reserch/VLDP/.venv/lib/python3.11/site-packages/geopy/geocoders/
 ↪nominatim.py:372, in Nominatim.reverse(self, query, exactly_one, timeout,␣
 ↪language, addressdetails, zoom, namedetails)
    370 logger.debug("%s.reverse: %s", self.__class__.__name__, url)
    371 callback = partial(self._parse_json, exactly_one=exactly_one)
--> 372 return self._call_geocoder(url, callback, timeout=timeout)

File ~/src/reserch/VLDP/.venv/lib/python3.11/site-packages/geopy/geocoders/base
 ↪py:368, in Geocoder._call_geocoder(self, url, callback, timeout, is_json,␣
 ↪headers)
    366 try:
    367     if is_json:
--> 368         result =␣
 ↪self.adapter.get_json(url, timeout=timeout, headers=req_headers)
    369     else:
    370         result = self.adapter.get_text(url, timeout=timeout,␣
 ↪headers=req_headers)

File ~/src/reserch/VLDP/.venv/lib/python3.11/site-packages/geopy/adapters.py:
 ↪472, in RequestsAdapter.get_json(self, url, timeout, headers)
    471 def get_json(self, url, *, timeout, headers):
--> 472     resp = self._request(url, timeout=timeout, headers=headers)
    473     try:
    474         return resp.json()
```

```
File ~/src/reserch/VLDP/.venv/lib/python3.11/site-packages/geopy/adapters.py:
 ↪494, in RequestsAdapter._request(self, url, timeout, headers)
    492         raise GeocoderServiceError(message)
    493     else:
--> 494         raise GeocoderUnavailable(message)
    495 elif isinstance(error, requests.Timeout):
    496     raise GeocoderTimedOut("Service timed out")

GeocoderUnavailable: HTTPSConnectionPool(host='nominatim.openstreetmap.org',␣
 ↪port=443): Max retries exceeded with url: /reverse?lat=39.975061&lon=116.
 ↪329201&format=json&accept-language=en&addressdetails=1 (Caused by␣
 ↪ReadTimeoutError("HTTPSConnectionPool(host='nominatim.openstreetmap.org',␣
 ↪port=443): Read timed out. (read timeout=1)"))
```

[ ]:
```
print("Head:")
print(latLongs[:6])
```

1.0.11 Data Preparation for CSV

In the code below we make our data ready for the use case. First, we condense the list of postcodes to the top 7 most used ones. The other are aggregated under "all_others". Then we will the missing entries with the "all_others" category as well and write the resulting data to a CSV file.

Note: the resulting .csv file might be slightly different from the one we created, the geodata api calls are not always consistent (timeouts may happen), so this could cause some changes. The overall file will be very similar though.

[ ]:
```
df = pd.DataFrame(latLongs, columns=["User", "day", "lat", "long", "postcode"])

# reduce the number of postcodes to the top 7, replace rest by "all_others"
top_postcodes = df.value_counts(subset="postcode").drop("None").nlargest(7).
 ↪keys()
df["postcode"] = df["postcode"].mask(df["postcode"].isin(top_postcodes) ==␣
 ↪False, "all_others")

# fill missing data
users = ["{:03d}".format(i) for i in range(182)]
days = 5
for day in range(days):
    for user in users:
        if not any((df["User"] == user) & (df["day"] == day)):
            df.loc[len(df)] = [user, day, None, None, "all_others"]

# Write to CSV
df.to_csv("geolife-postcodes-condensed-empties.csv", index=False)
```

1.0.12 Inspect the final dataset distribution

Below we look at the true distribution of the resulting dataset

[ ]:
```
df = pd.read_csv("geolife-postcodes-condensed-empties.csv")
days = df['day'].unique()
users = df['User'].unique()
counts = {}
for day in days:
    counts[day] = {}
    postcodes = df.loc[df['day'] == day, 'postcode'].unique()
    for postcode in postcodes:
        counts[day][postcode] = df[(df['day'] == day) & (df['postcode'] ==␣
 ↪postcode)].shape[0]

for day in counts:
    c = 0
    for k, v in counts[day].items():
        print(k, v)
        c = c + v
    print(f"This count: {c}")
    print()
```

1.0.13 DP Parameters and Example Run (Use Case 2)

[ ]:
```
# Total number of users
users = df["User"].unique()
n = len(users)
postcodes = df["postcode"].unique()
k = len(postcodes)  # histogram of postcodes
eps = 2  # Target (eps, delta)-guarantee required
# over multiple runs the eps add up, e.g., 5 runs => 5*eps
delta = 1e-4

rrk = RRMechanism(k=k)  # we have the range of {0, 1, ..., k}

bound_types = [Hoeffding, BennettExact]
all_bounds = []
for B in bound_types:
    all_bounds.append(B(rrk))

print(f"Epsilon: {eps}", eps)
print(f"Delta: {delta}")
print(f"Number of participants: {n}")
bounds = {b.get_name(): b.get_eps0(eps, n, delta) for b in all_bounds}
print(f"Bounds: {bounds}")

gamma = rrk.get_gamma()[0]
```

```
print(f"Gamma: {gamma}")

days = df["day"].unique()


def RRMech(x, gamma, postcodes):
    if not np.random.binomial(1, gamma):
        return x
    else:
        return np.random.choice(postcodes)


orig_dict = {}
syn_dict = {}

# do an example run
i = 0
for day in days:
    i += 1
    orig_dict[day] = {}
    syn_dict[day] = {}
    df0 = df[['User', 'day', 'postcode']]
    df1 = df0[df0['day'] == day]
    for user in users:
        postcode = df1.loc[df1['User'] == user, 'postcode'].values
        #print(postcode)
        if postcode.size != 0:
            postcode = postcode[0]
            if postcode in orig_dict[day]:
                orig_dict[day][postcode] += 1
            else:
                orig_dict[day][postcode] = 1
            priv_postcode = RRMech(postcode, gamma, postcodes)
            if priv_postcode in syn_dict[day]:
                syn_dict[day][priv_postcode] += 1
            else:
                syn_dict[day][priv_postcode] = 1

    print("Run " + str(i) + ":")
    print("Postcode, DP, Original:")
    print("==========\n")
    for k, v1 in syn_dict[day].items():
        v2 = orig_dict[day][k]
        print(k + ", " + str(v1) + ", " + str(v2))
```