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In this exercise, I will try to implement a localization model.
The input is GPS and IMU data.
The output is a 3-dim pose(x, y, z)
I will use the Kitti-tracking-GPS IMU dataset.

The code is in:
https://github.com/wennycooper/AIOT_Exercise_3

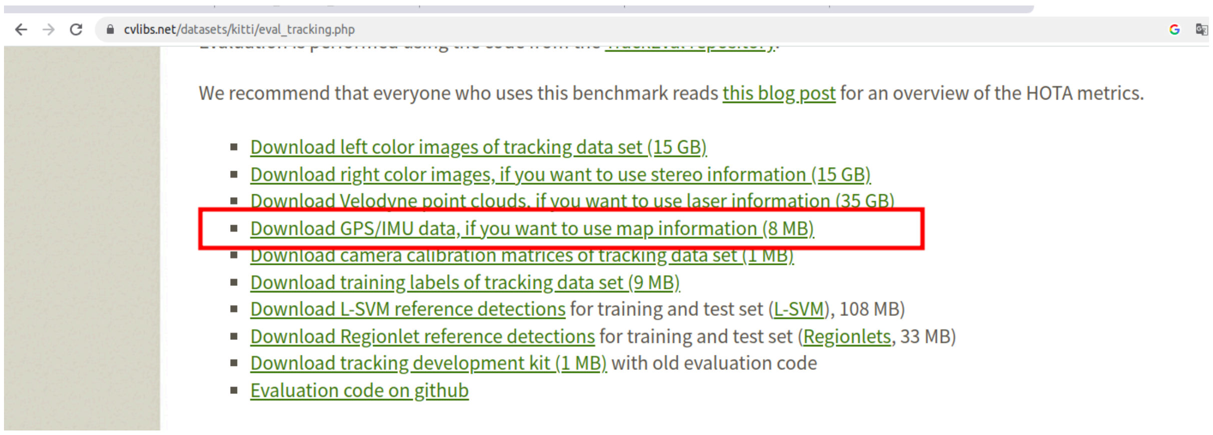
Here are the overall steps.

1. Load the Kitti-Track GPS/IMU dataset (30-dim)
2. Normalise the dataset
3. Construct the model
4. Train the model
5. Inference the result
6. Evaluate
7. Conclusion
8. Other attempts

Here is the details:

1. Load Kitti-Track dataset

In the Kitti-Track dataset, they provide 21 sequences of training set and 29 sequences of testing set. It is downloaded from Kitti official site as below.


cvlibs.net/datasets/kitti/eval_tracking.php

We recommend that everyone who uses this benchmark reads this blog post for an overview of the HOTA metrics.

- Download left color images of tracking data set (15 GB)
- Download right color images, if you want to use stereo information (15 GB)
- Download Velodyne point clouds, if you want to use laser information (35 GB)
- Download GPS/IMU data, if you want to use map information (8 MB)
- Download camera calibration matrices of tracking data set (1 MB)
- Download training labels of tracking data set (9 MB)
- Download L-SVM reference detections for training and test set (L-SVM), 108 MB)
- Download Regionlet reference detections for training and test set (Regionlets, 33 MB)
- Download tracking development kit (1 MB) with old evaluation code
- Evaluation code on github

Fig, 1 Download KITTI Track dataset

The dataset is in OXTS format which contains 30-dim GPS and IMU information.
In the last 7 fields, there seems to be not much information about the localization. So I will use the 23 fields.

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GPS/IMU 3D localization unit
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The GPS/IMU information is given in a single small text file which is
written for each synchronized frame. Each text file contains 30 values
which are:

  - lat:     latitude of the oxts-unit (deg)
  - lon:     longitude of the oxts-unit (deg)
  - alt:     altitude of the oxts-unit (m)
  - roll:    roll angle (rad),  0 = level, positive = left side up (-pi..pi)
  - pitch:   pitch angle (rad), 0 = level, positive = front down (-pi/2..pi/2)
  - yaw:     heading (rad),     0 = east,  positive = counter clockwise (-pi..pi)
  - vn:      velocity towards north (m/s)
  - ve:      velocity towards east (m/s)
  - vf:      forward velocity, i.e. parallel to earth-surface (m/s)
  - vl:      leftward velocity, i.e. parallel to earth-surface (m/s)
  - vu:      upward velocity, i.e. perpendicular to earth-surface (m/s)
  - ax:      acceleration in x, i.e. in direction of vehicle front (m/s^2)
  - ay:      acceleration in y, i.e. in direction of vehicle left (m/s^2)
  - az:      acceleration in z, i.e. in direction of vehicle top (m/s^2)
  - af:      forward acceleration (m/s^2)
  - al:      leftward acceleration (m/s^2)
  - au:      upward acceleration (m/s^2)
  - wx:      angular rate around x (rad/s)
  - wy:      angular rate around y (rad/s)
  - wz:      angular rate around z (rad/s)
```

- wf: angular rate around forward axis (rad/s)
- wl: angular rate around leftward axis (rad/s)
- wu: angular rate around upward axis (rad/s)
- posacc: velocity accuracy (north/east in m)
- velacc: velocity accuracy (north/east in m/s)
- navstat: navigation status
- numsats: number of satellites tracked by primary GPS receiver
- posmode: position mode of primary GPS receiver
- velmode: velocity mode of primary GPS receiver
- orimode: orientation mode of primary GPS receiver

Fig, 2 OXTS format

They didn’t provide the ground_truth pose. So I use lon,lat,plt to UTM conversion to obtain the ground_truth pose.

https://en.wikipedia.org/wiki/Universal_Transverse_Mercator_coordinate_system#From_latitude,_longitude_(%CF%86,_%CE%BB)_to_UTM_coordinates_(E,_N)

It is implemented in:

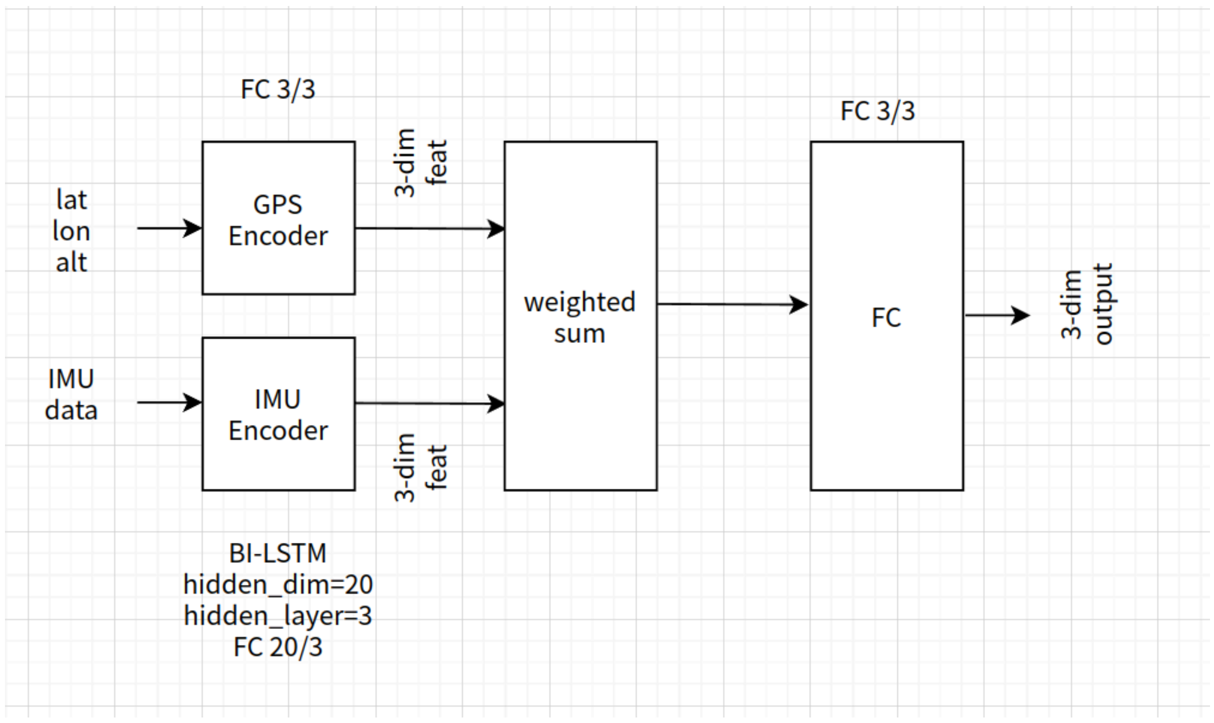
- **load_oxts.py**
  # compute GT pose and save dataset to pickle file

2. Normalise the dataset

- Normalized_data [lon, lat, alt, r, p, y …] = (data - mean) / std   #(N, 23)
- normalized_pose [r,p,y] = (pose - mean_pose)) / std_pose   #(N, 3)

3. Construct the model

The model structure is as below. We leveraged the PointNet to solve the number points varying problem.



The main idea is, the pose can be roughly computed in linear to obtain the x,y,z pose. So I will just use a 3x3 Fully-Connected layer GPS encoder to encode the GPS feature.

The IMU encoder is a BI-LSTM + a FC layer. The BI-LSTM is a dynamic mapping module to encode the IMU data. I think it can help to obtain the pose mode precisely. Then I use a weighted sum to sum up the GPS encoder and IMU encoder features. The last layer is a FC 3 by 3 layer to output the 3-dim x,y,z pose.

4. Train the model

The **train.py** is the implementation for section 2, 3 and 4.

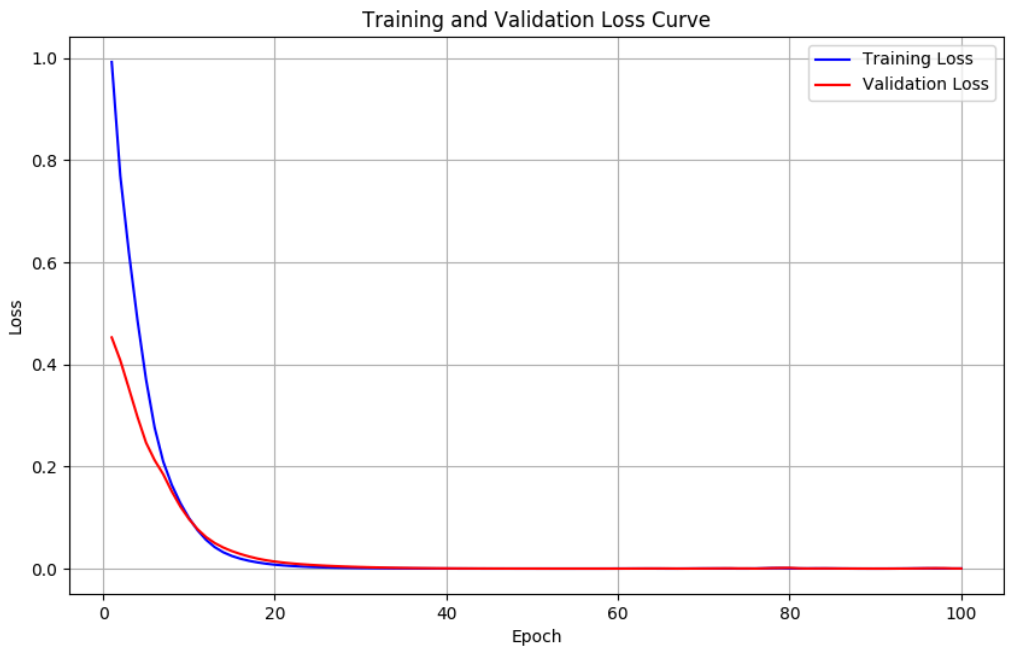
Here are the training environment and hyperparameters:

- GPU: RTX-3090 (24GB)
- Batch_size: 64 (due to VRAM restriction)
- Lr: 1e-3

- Weighted sum: GPS: 1.0, IMU: 0.1
- Loss function: MSE
- Training time: 1.2 hrs
- Epoch: 100

The dataset sequence 00 ~ 20 is for training and the sequence 21 ~ 50 is for validation.

Here is the training curve.



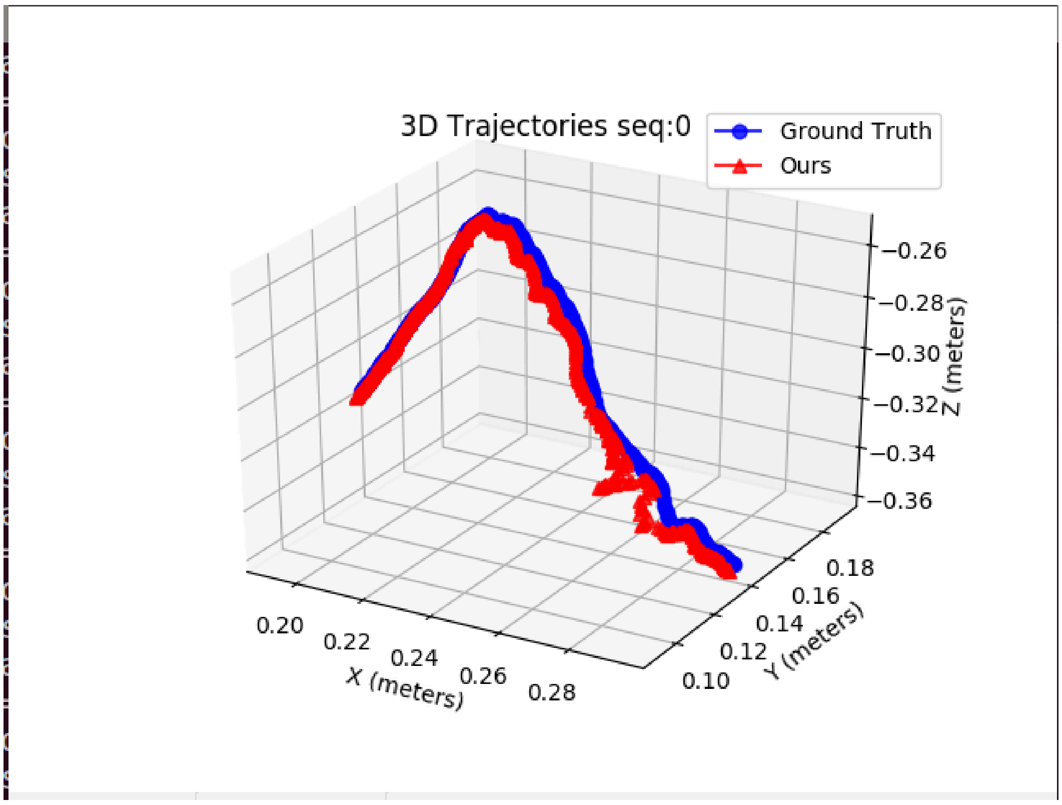
5. Inference the result

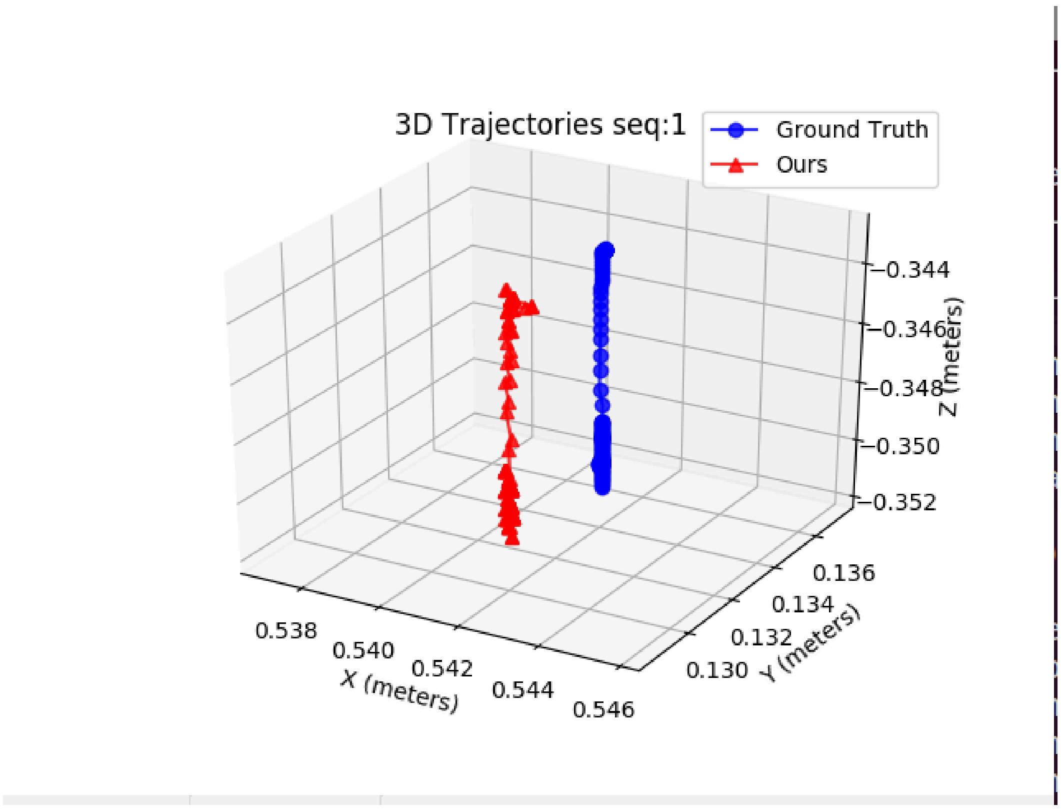
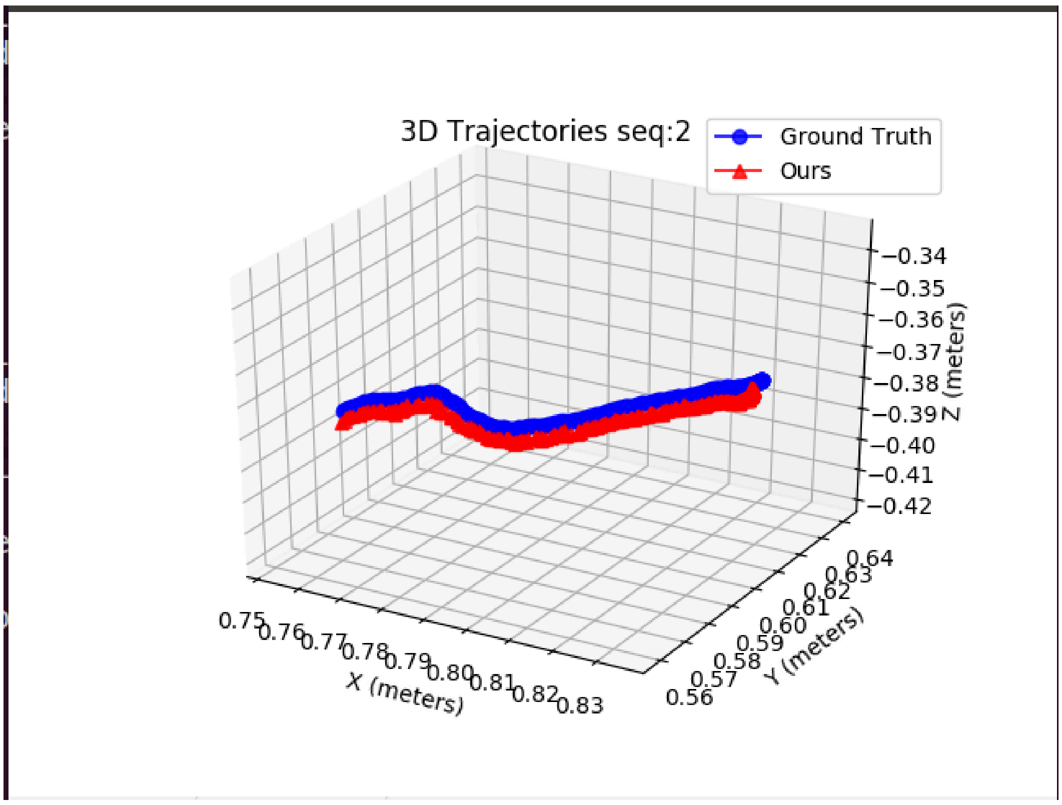
The inference code is in **inference_by_seq.py**
It outputs 3-dim pose by specific sequence_index.

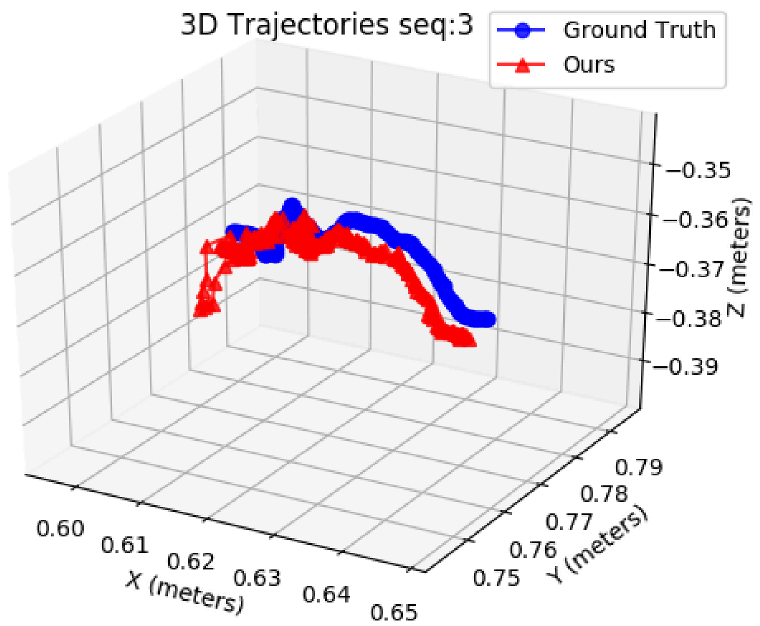
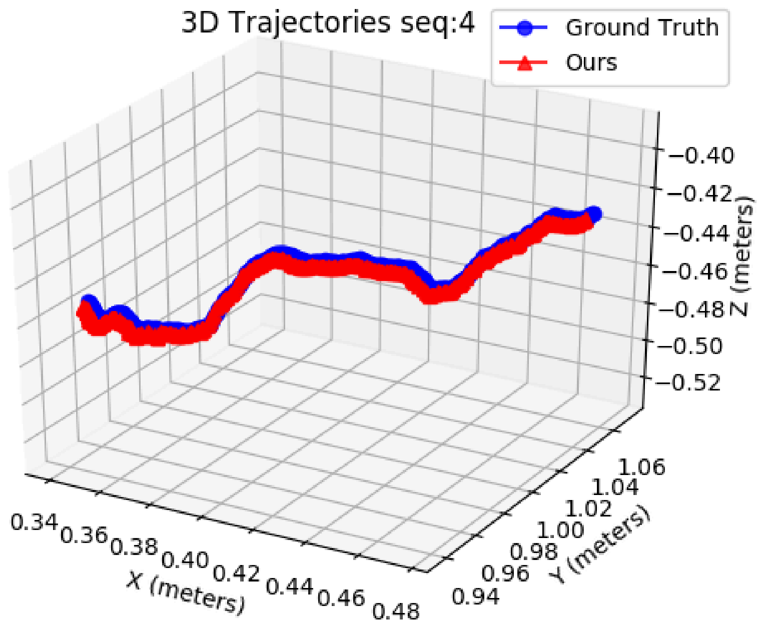
6. Evaluate the result

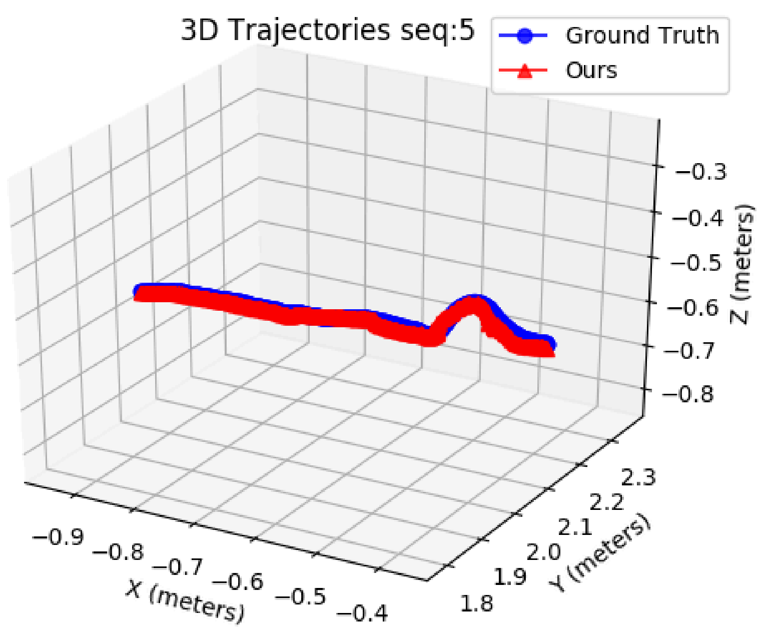
Then we can evaluate the testing set results.

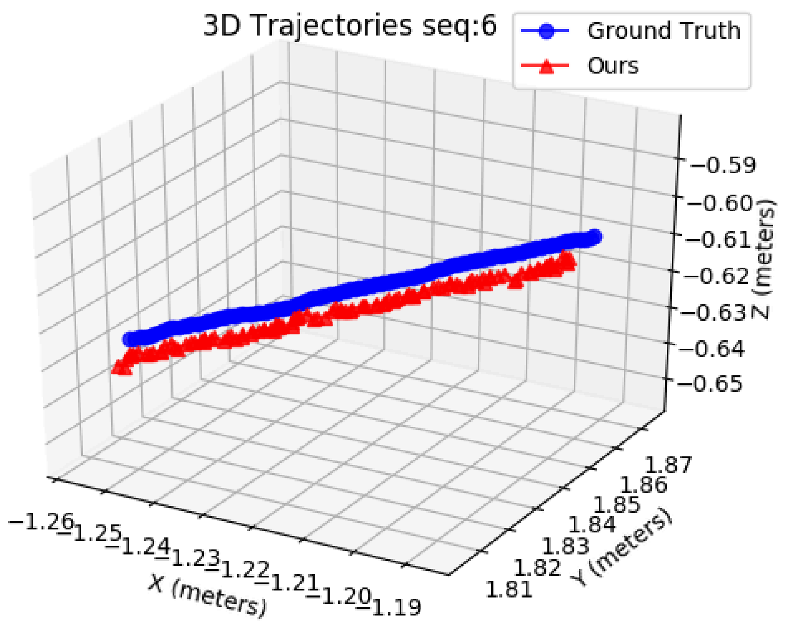
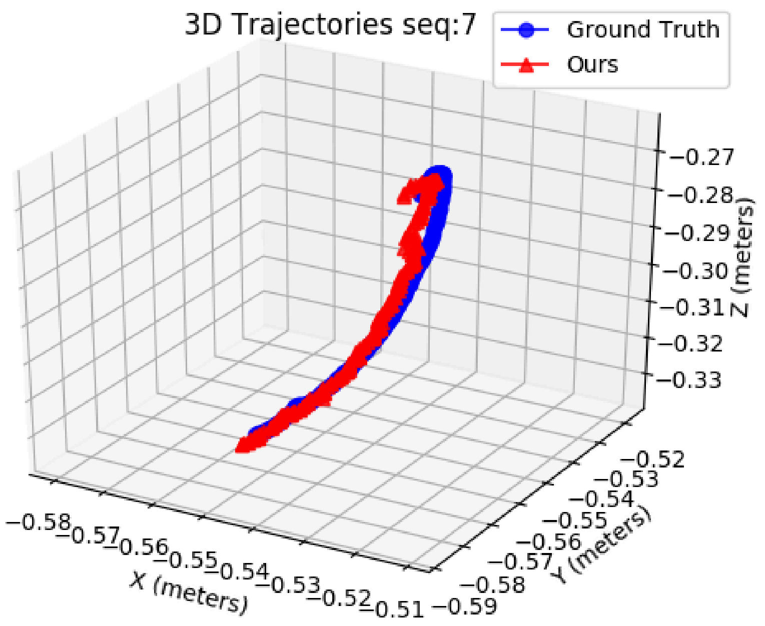
Following is the result for each sequence(00 ~ 28).
The trajectory in blue is the ground_truth and the trajectory in brown is my result.
The errors information is below the trajectory in each sequence

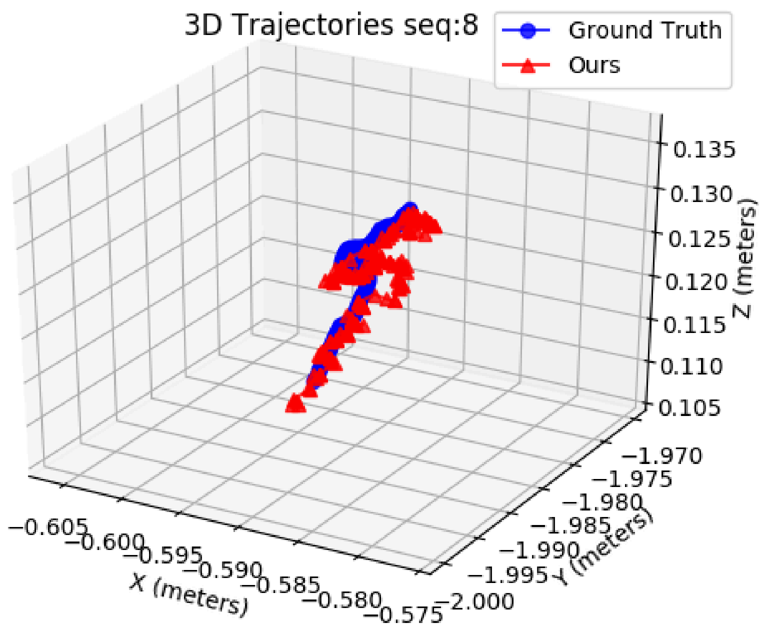
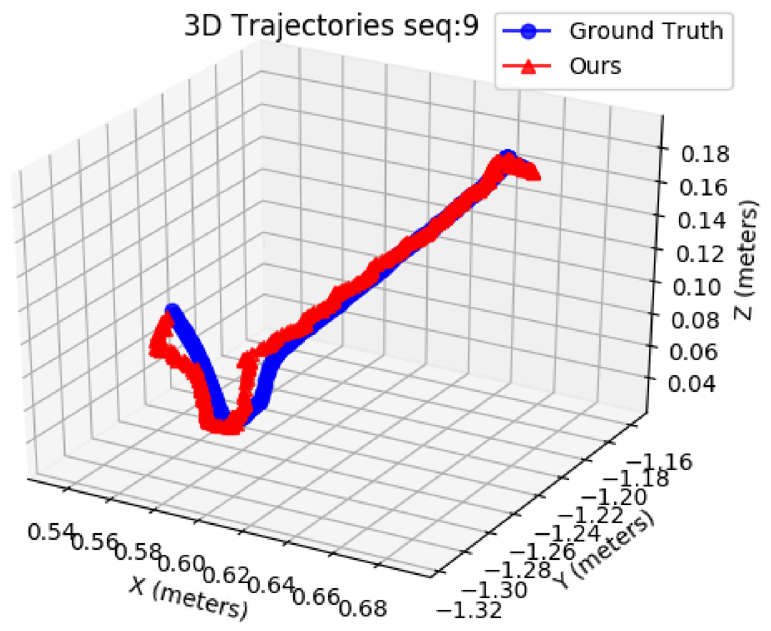
Seq	Trajectory comparison, ATE(m) and Translation Error(%)
00	 Absolute Translation Error (m): 0.0034 Translation Error (%): 0.83%

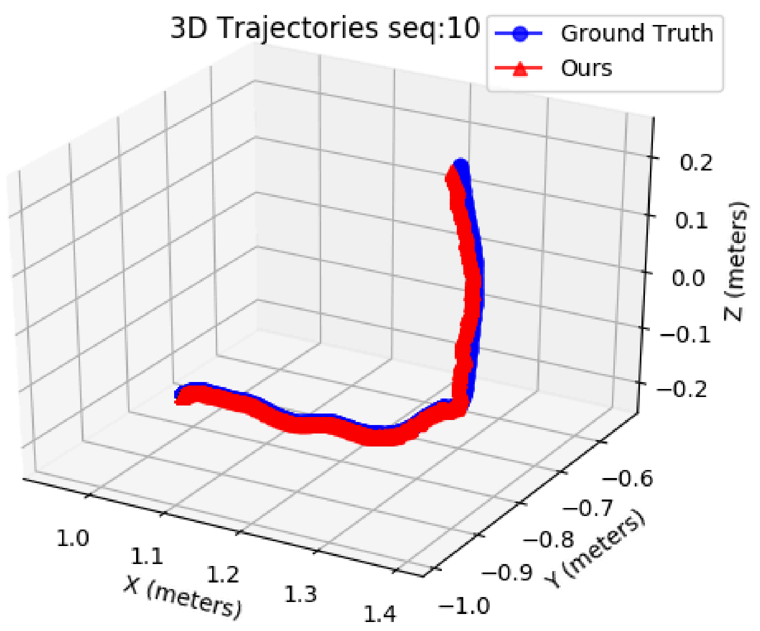
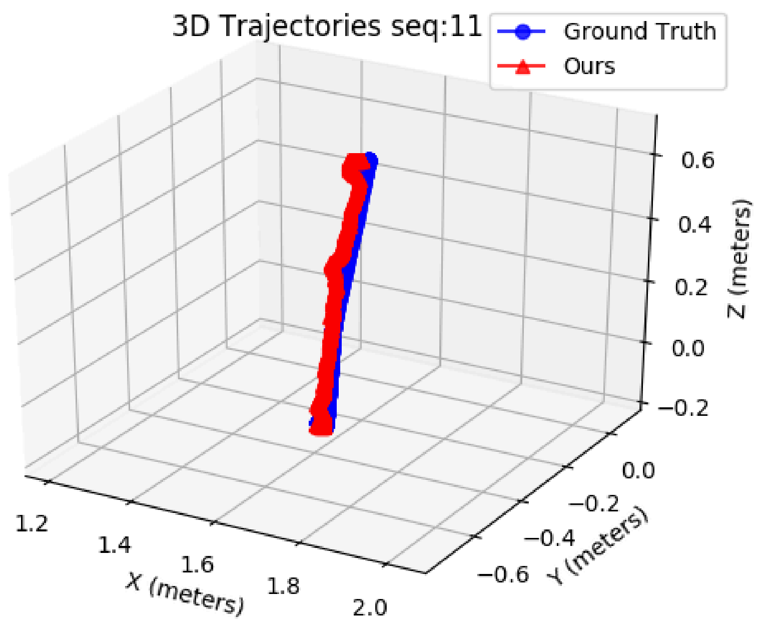
01	 Absolute Translation Error (m): 0.0026 Translation Error (%): 0.39%
02	 Absolute Translation Error (m): 0.0048 Translation Error (%): 0.45%

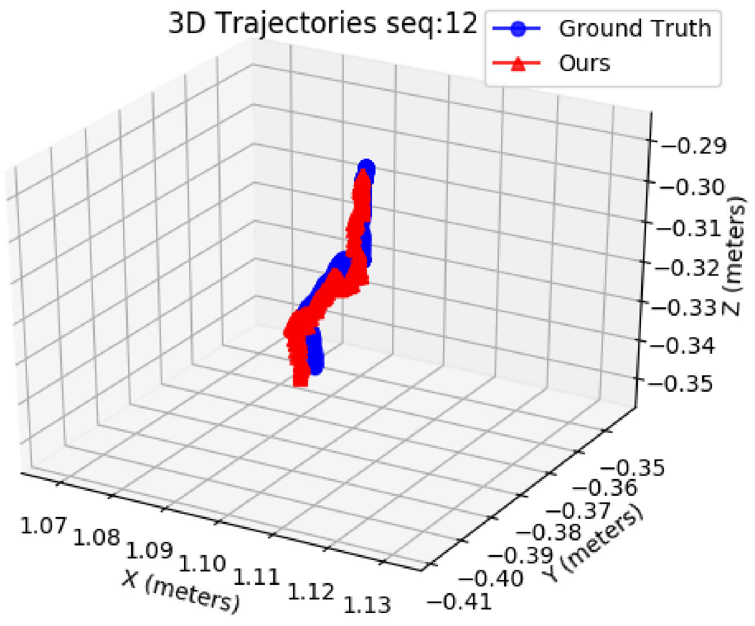
03	 Absolute Translation Error (m): 0.0049 Translation Error (%): 0.47%
04	 Absolute Translation Error (m): 0.0055

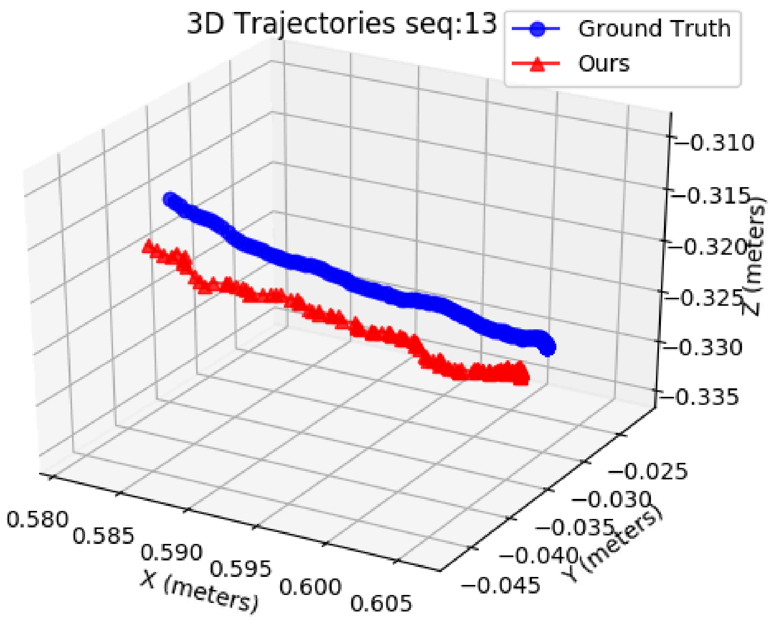
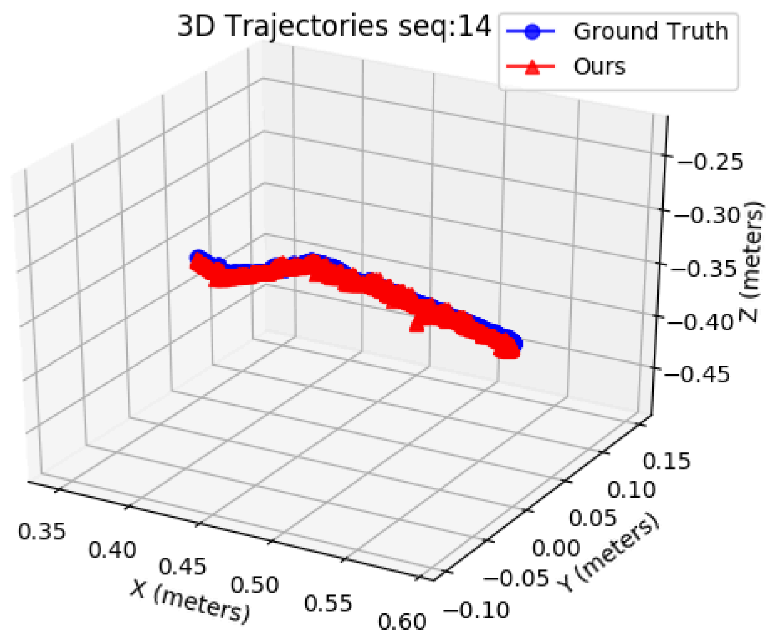
	Translation Error (%): 0.46%
05	 Absolute Translation Error (m): 0.0151 Translation Error (%): 0.67%

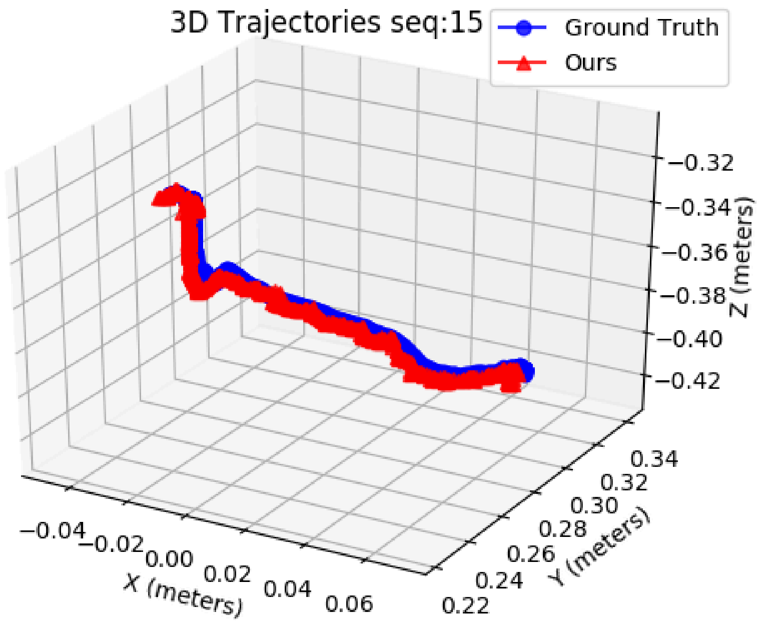
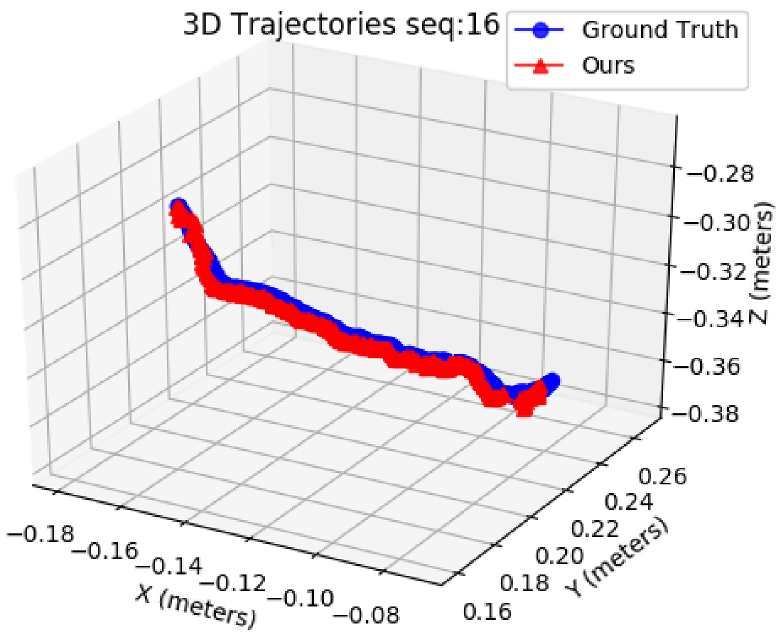
06	 Absolute Translation Error (m): 0.0134 Translation Error (%): 0.59%
07	 Absolute Translation Error (m): 0.0039 Translation Error (%): 0.47%

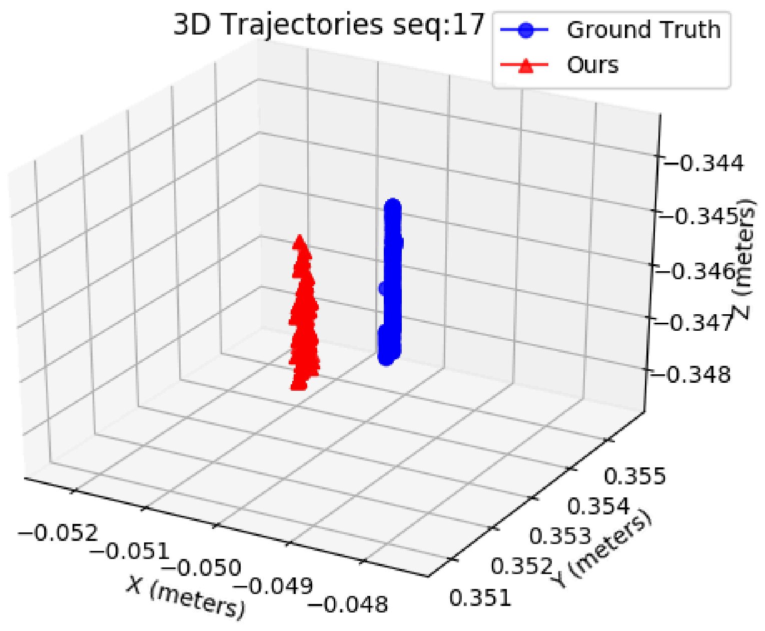
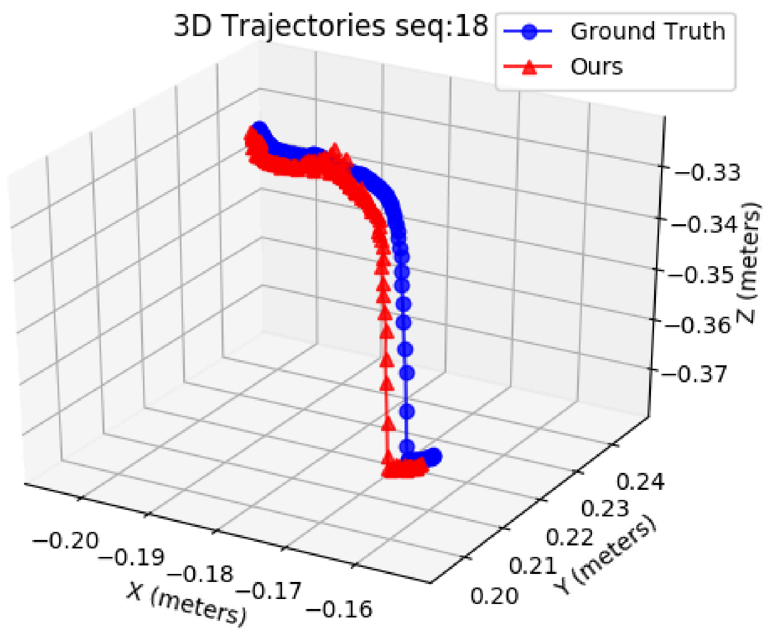
08	 Absolute Translation Error (m): 0.0063 Translation Error (%): 0.30%
09	 Absolute Translation Error (m): 0.0077

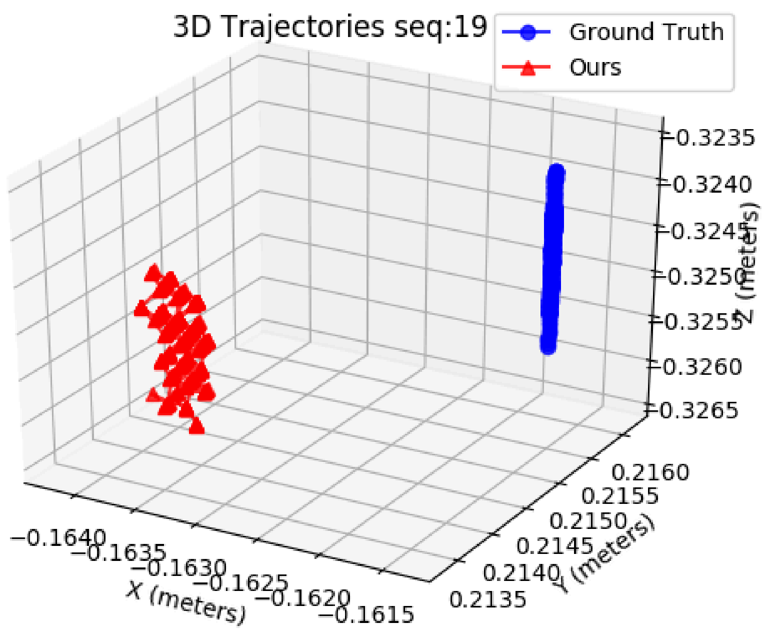
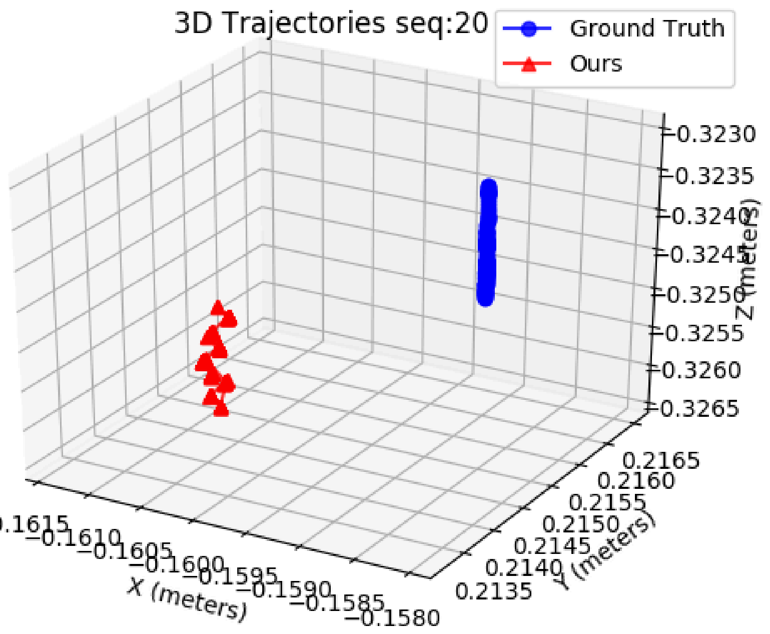
	Translation Error (%): 0.56%
10	 Absolute Translation Error (m): 0.0085 Translation Error (%): 0.59%
11	

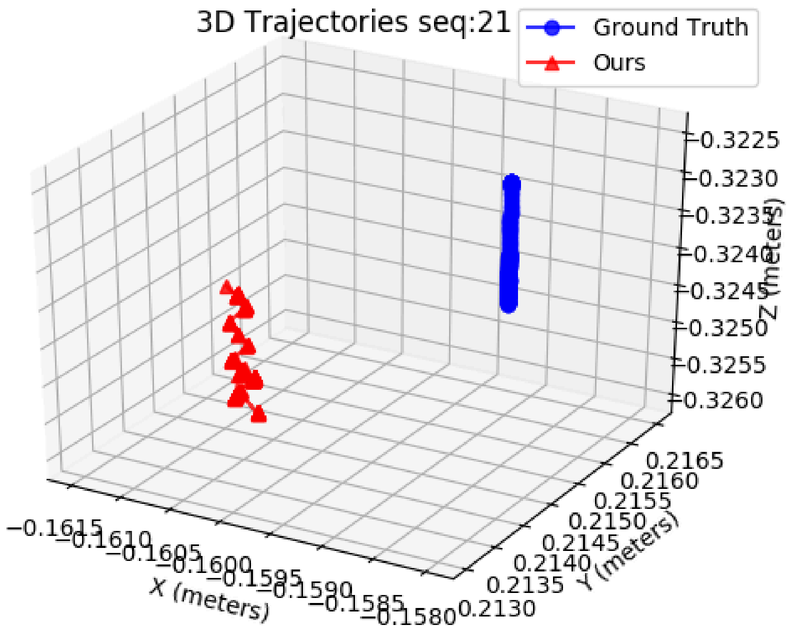
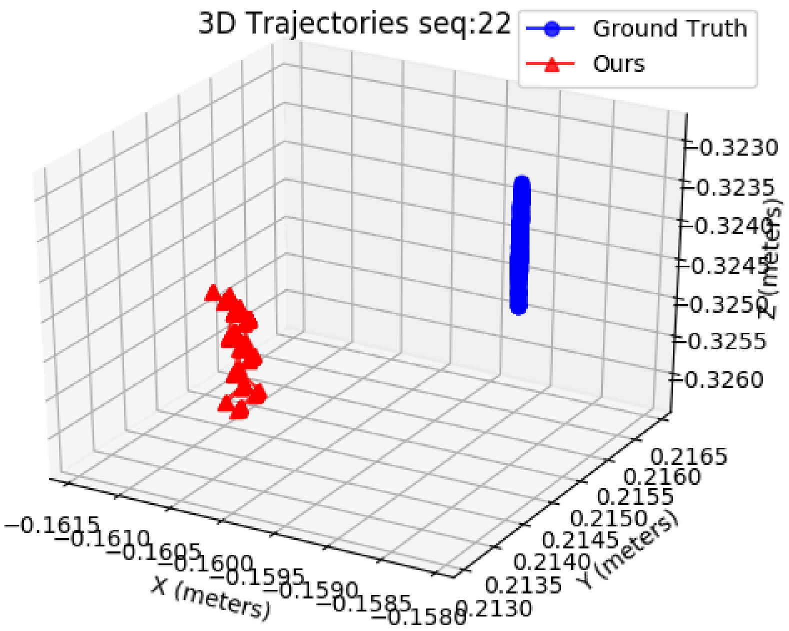
	Absolute Translation Error (m): 0.0196 Translation Error (%): 1.15%
12	 Absolute Translation Error (m): 0.0046 Translation Error (%): 0.38%

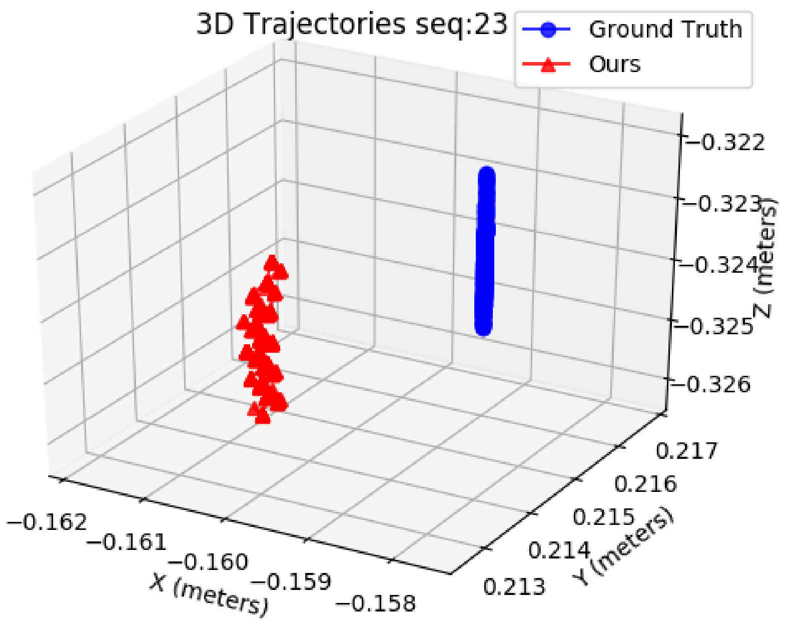
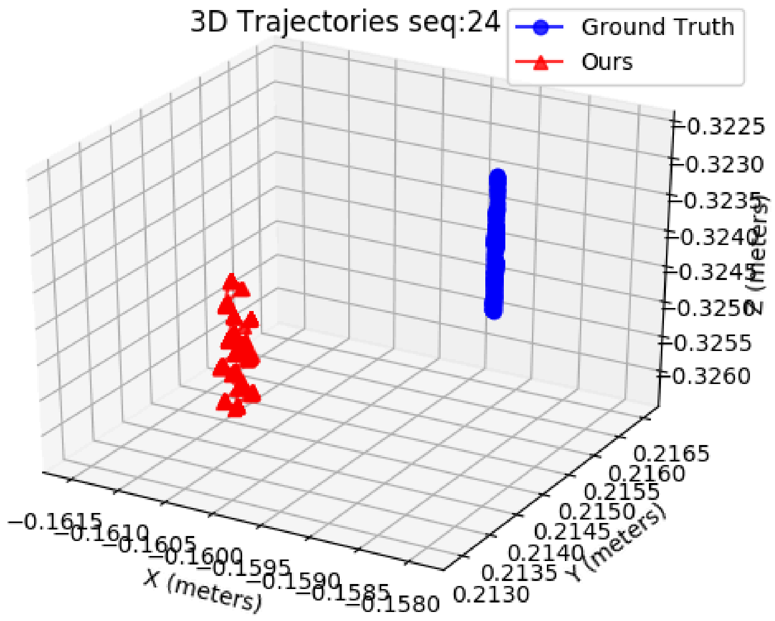
13	 Absolute Translation Error (m): 0.0036 Translation Error (%): 0.53%
14	 Absolute Translation Error (m): 0.0032 Translation Error (%): 0.55%

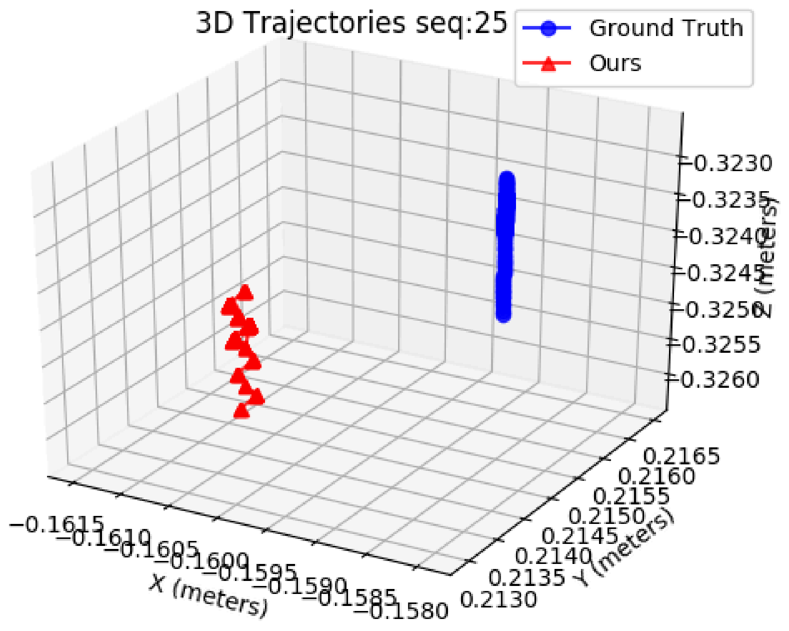
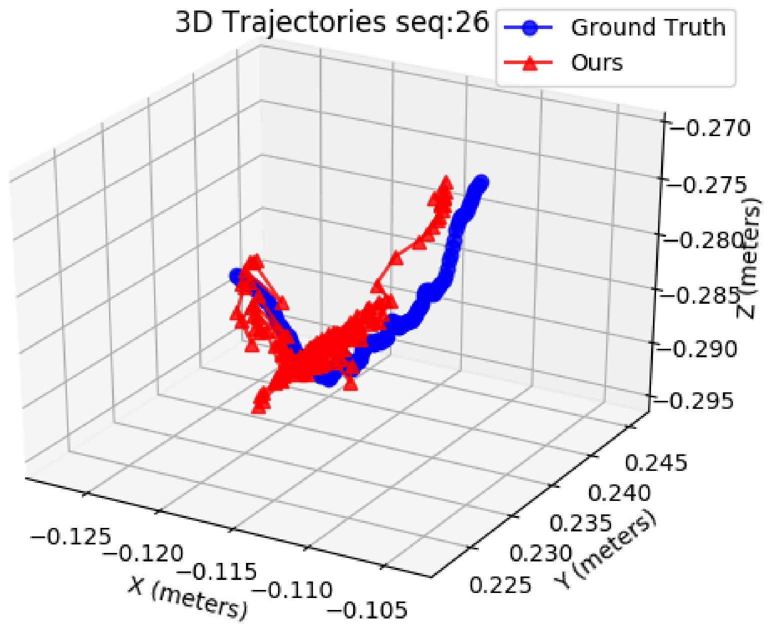
15	 Absolute Translation Error (m): 0.0032 Translation Error (%): 0.67%
16	 Absolute Translation Error (m): 0.0035 Translation Error (%): 0.85%

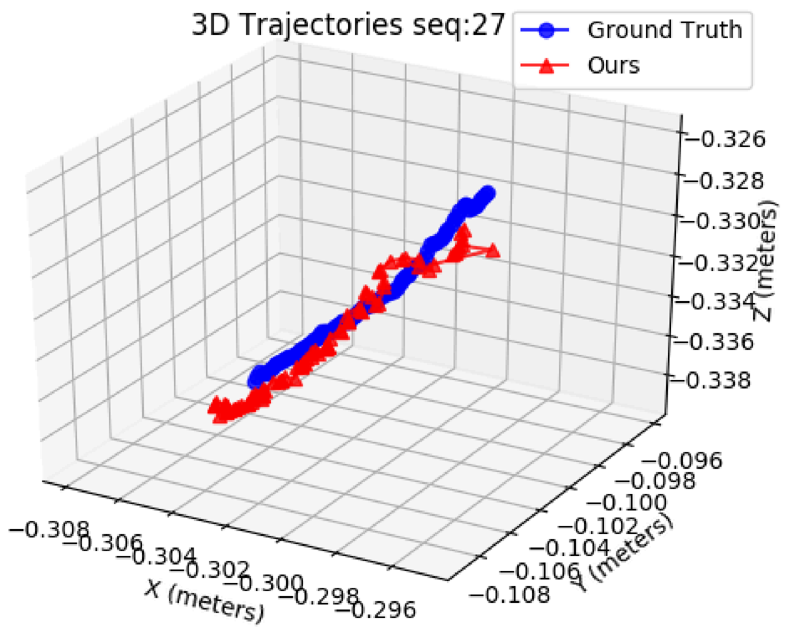
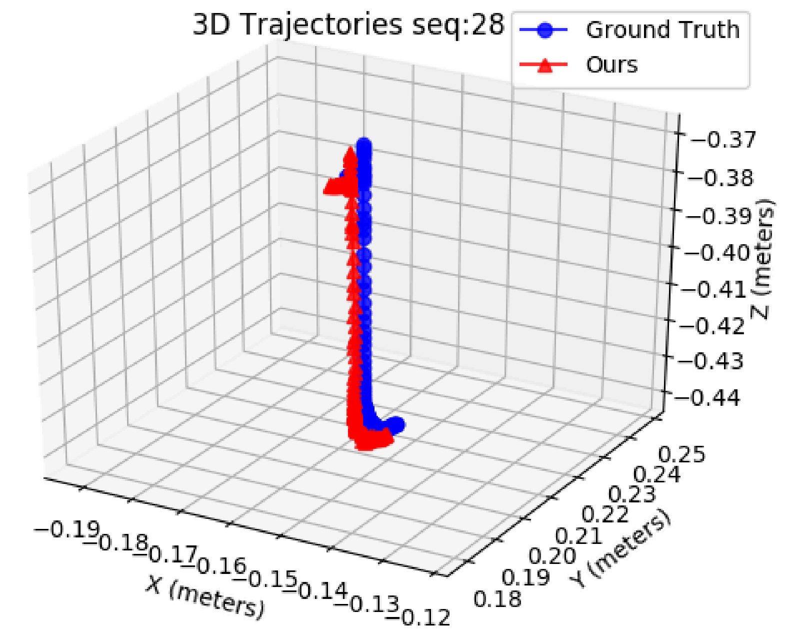
17	 Absolute Translation Error (m): 0.0047 Translation Error (%): 0.95%
18	 Absolute Translation Error (m): 0.0038 Translation Error (%): 0.88%

19	 Absolute Translation Error (m): 0.0031 Translation Error (%): 0.74%
20	 Absolute Translation Error (m): 0.0035 Translation Error (%): 0.83%

21	 Absolute Translation Error (m): 0.0035 Translation Error (%): 0.83%
22	 Absolute Translation Error (m): 0.0035 Translation Error (%): 0.83%

23	 Absolute Translation Error (m): 0.0035 Translation Error (%): 0.82%
24	 Absolute Translation Error (m): 0.0035 Translation Error (%): 0.83%

25	 Absolute Translation Error (m): 0.0035 Translation Error (%): 0.83%
26	 Absolute Translation Error (m): 0.0048 Translation Error (%): 1.22%

27	 Absolute Translation Error (m): 0.0028 Translation Error (%): 0.60%
28	 Absolute Translation Error (m): 0.0034 Translation Error (%): 0.68%

8. Conclusions

I think the result is not bad. Maybe it’s because this is not a very difficult problem.