

1 Supplementary Material

2 Section A provides additional details for the method. The experiment details are described in Section
3 B, including experimental setup and results. We also present more qualitative results in Section C.

4 A Method details

5 A.1 Cross-modal Interaction

6 **Trajectory Encoder.** The trajectory encoder aims to learn the human motion representation via
7 a transformer structure. The observed trajectory of person p is X_p with the size of $T_{pas} \times 2$ (e.g.,
8 $T_{pas} = 10$ in PAV). We obtain the human motion with the size of $10 \times 4 \times 512$ using $N_{tra} = 4$
9 self-attention layers, where 512 is the embed dimension. We reshape the motion features from size
10 $10 \times 4 \times 512$ to 10×2048 and project it from dimension 10×2048 to 10×512 . Thus, we obtain
11 the human motion representation X_{tra} on PAV dataset with the size of 10×512 .

12 **Scene Encoder.** The scene encoder is to extract the environment information. The scene semantic
13 features are with the size of $150 \times 56 \times 56$, where 150 is the number of semantic classes. We reshape
14 the semantic features from size $(150 \times 56 \times 56)$ to $(150 \times 3, 136)$, and project them from dimension
15 $(150 \times 3, 136)$ to (150×512) through a Multi-Layer Perception layer. As a result, we obtain the
16 scene representation X_{sce} with the size of 150×512 .

17 **Cross-modal Transformer.** The cross-modal transformer with $N_{cro} = 6$ layers aims to learn
18 the interaction between human motion and environment information. We obtain the inter-modal
19 representation $(\hat{X}_{tra}, \hat{X}_{sce})$ via the cross-modal transformer. The size of \hat{X}_{tra} and \hat{X}_{sce} are 10×512
20 and 150×512 , respectively. We take the last element (LE) $h_{tra} \in \mathbb{R}^{512}$ of \hat{X}_{tra} and the output
21 $h_{sce} \in \mathbb{R}^{512}$ of \hat{X}_{sce} after the global pooling layer (GPL), and get the offsets $O_p \in \mathbb{R}^{50 \times 2}$
22 ($T_{fut} = 50$ in PAV) through a Multi-Layer Perception layer.

23 A.2 Training

24 We use the curve smoothing (CS) regression loss \mathcal{L}_{cs} to reduce the impact of randomness and
25 subjectivity. The quadratic Bézier curve is adopted to smooth the trajectory, which can be formulated
26 as follows:

$$CS(Z_p, t) = (1-t)^2 z_p^{-T_{pas}+1} + 2(1-t)t z_p^{T'} + t^2 z_p^{T_{fut}}, \quad 0 \leq t \leq 1 \quad (1)$$

27 where $z_p^{-T_{pas}+1}$ is the starting point of the trajectory, and $z_p^{T_{fut}}$ is the destination of the trajectory.
28 $z_p^{T'}$ is the control point of this trajectory, which can be calculated as follows:

$$z_p^{T'} = (1-t)z_p^{-T_{pas}+1} + tz_p^{T_{fut}} \quad (2)$$

29 Then we divide the time period $t \in [0, 1]$ equidistantly, and get the smoothed trajectory $\bar{Z}_p =$
30 $[\bar{X}_p; \bar{Y}_p] = \{\bar{z}_p^t\}_{t=-T_{pas}+1}^{T_{fut}}$.

31 B Experiments

32 B.1 Experimental Setup

33 **Dataset Details.** ETH/UCY datasets are the benchmark commonly used for human trajectory
34 prediction. The benchmark contains videos from 5 scenes, including ETH, HOTEL, UNIV, ZARA1,
35 and ZARA2. Following [19], we sample the frames at 2.5 HZ and predict future $n_{fut} = 12$ frames
36 given the observed $n_{pas} = 8$ frames. We use the preprocessed data provided by YNet [19], which
37 converts the raw data from word coordinate into image pixel space. We use the leave-one-scene-out
38 strategy with 4 scenes for training and the remaining scene for testing. PAV is a more challenging
39 dataset with diverse movement patterns, which includes 3 videos PETS, ADL, and VENICE. We
40 divide the videos into training (80%) and testing (20%) sets, and PETS/ADL/VENICE contain

41 2,370/2,935/4,200 training sequences and 664/306/650 testing sequences, respectively. We use
 42 observed $n_{pas} = 10$ frames to predict future $n_{fut} = 50$ frames.

43 **Evaluation Metrics.** For ETH and UCY datasets, we adopt the standard metrics (*i.e.*, ADE and FDE).
 44 Due to the limitations discussed in Section 4.1, we introduce curve smoothing (CS) into current
 45 metrics on PAV dataset, and thus we propose CS-ADE and CS-FDE. The curve smoothing function
 46 is defined as the same as Equation 1.

47 B.2 Experimental Results

48 **PAV without CS.** We conduct experiments on PAV using the traditional ADE/FDE metrics. Table 1
 49 shows the quantitative result of our method and previous human trajectory prediction methods. Com-
 50 pared to the state-of-the-art results of YNet, the proposed SHENet achieves 5.1%/4.0% improvement
 51 over ADE/FDE on average. In particular, our method improves the FDE by 13.6% on PETS.

Table 1: Comparison with SOTA methods on PAV dataset.

Method	Evaluation metrics: ADE ↓ / FDE ↓ (in pixels)			
	PETS	ADL	VENICE	AVG
SS-LSTM [35]	57.75 / 120.23	24.84 / 57.03	116.77 / 36.37	33.12 / 71.21
Social-STGCN [22]	63.76 / 159.30	31.29 / 73.09	19.38 / 43.13	38.14 / 91.84
Next [16]	51.78 / <u>109.58</u>	24.14 / 60.06	<u>12.38</u> / 25.96	29.43 / 65.20
MANTRA [20]	<u>49.87</u> / 110.14	25.78 / 58.12	16.79 / 39.50	30.81 / 69.25
YNet [19]	53.46 / 117.81	21.95 / 45.88	12.29 / <u>26.61</u>	<u>29.23</u> / <u>63.43</u>
SHENet (Ours)	46.31 / 101.74	<u>22.46</u> / <u>50.71</u>	14.43 / 30.21	27.73 / 60.89

52 **ETH/UCY without Video Data.** We also conduct the experiments on ETH/UCY without using the
 53 video data, shown in Table 2. Since MANTRA didn't conduct experiments on ETH/UCY, we use the
 54 results of MANTRA reported in the work [31].

Table 2: Comparison of state-of-the-art (SOTA) methods on ETH/UCY datasets. The best-of-20 is adopted for evaluation.

Method	Evaluation metrics: ADE ↓ / FDE ↓ (in meters)					AVG
	ETH	HOTEL	UNIV	ZARA1	ZARA2	
Social-STGCNN [22]	0.64 / 1.11	0.49 / 0.85	0.44 / 0.79	0.34 / 0.53	0.30 / 0.48	0.44 / 0.75
MANTRA [20]	0.48 / 0.88	0.17 / 0.33	0.37 / 0.81	0.27 / 0.58	0.30 / 0.67	0.32 / 0.65
YNet [19]	0.28 / 0.33	0.10 / 0.14	0.24 / 0.41	0.17 / 0.27	0.13 / 0.22	0.18 / 0.27
MemoNet [32]	0.40 / 0.61	0.11 / 0.17	0.24 / 0.43	0.18 / 0.32	0.14 / 0.24	0.21 / 0.35
SHENet (Ours)	0.37 / 0.58	0.17 / 0.28	0.26 / 0.43	0.21 / 0.34	0.18 / 0.30	0.24 / 0.39

55 From Table 2, we can note that our method achieves the comparable performance without using the
 56 video data.

57 **SDD.** We also report the performance of different methods on SDD in Table 3. It shows that our
 58 model performs a little bit worse than the results of YNet [19] and MemoNet [32]. Nevertheless, our

Table 3: Comparison of state-of-the-art (SOTA) methods on SDD dataset. The best-of-20 is adopted for evaluation.

Method	MANTRA [20]	PECNet [18]	YNet [19]	MemoNet [32]	SHENet (Ours)
ADE	8.96	9.96	7.85	8.56	9.01
FDE	17.76	15.88	11.85	12.66	13.24

59 method performs better than previous baselines (such as PECNet [18], MANTRA [20]). Consequently,
 60 our method can achieve reasonable performance in bird-eye-view scenario.

61 B.3 Analysis

62 **Distance Threshold θ .** θ is used to determine the update of trajectory bank. The typical value of θ is

set according to the trajectory length. When the ground truth trajectory is longer in terms of pixel, the absolute value of prediction error is usually larger. However, their relative errors are comparable. Thus, the θ is set to be 75% of the training error when the error converges. In our experiments, we set $\theta = 25$ in PETS, and $\theta = 6$ in ADL. The "75% of the

Table 4: Comparison between different parameter θ on PAV dataset. Results are the average of the three scenarios.

θ	25%	50%	75%	100%
ADE	22.82	20.48	18.89	20.78
FDE	58.28	51.67	45.13	54.52

63 training error" is obtained from the experimental result, shown in Table 4.

Different K in K-medoids. We study the effect of setting different number of initial clusters K , shown in Table 5. We can note that the initial number of clusters is not sensitive to the prediction results, especially when the initial number of clusters is 24-36. Therefore, we can set K to 32 in our experiments.

Table 5: Comparison between the initial number of clusters K on PAV dataset.

K	24	28	32	36
ADE	19.28	19.23	18.89	19.17
FDE	45.48	45.59	45.13	45.62

64 **Analysis for Bank Complexity.** The time complexity of the searching and updating are $O(N)$
 65 and $O(1)$. Their space complexity is $O(N)$. The group trajectory number $N \leq 1000$. The time
 66 complexity of the clustering process is $O(\beta^2 + MK\beta)$, and the space complexity is $O(\beta^2 + M\beta)$.
 67 β is the number of trajectories for clustering. K is the number of clusters, and M is the number of
 68 iterations for clustering methods.

69 C Qualitative Results

70 Figure 1 presents the visualization of clustered trajectories. We can see that similar trajectories are
 71 clustered into the same group. Each group trajectory represents a moving pattern of a group of people.
 72 Figure 2 illustrates the qualitative results of SHENet and other methods. Our method is superior to
 73 others when it comes to human crossing intersections (e.g., the first row in Figure 2) or turning (e.g.,
 74 the second row in Figure 2). Figure 3 includes the qualitative results of our SHENet without/with
 75 curve smoothing (CS). The first row presents the results of using MSE loss \mathcal{L}_{tra} . We can note that
 76 our SHENet can not provide a correct path from scene history, since there exists some noise (e.g.,
 77 abrupt and sharp turns) in past trajectories. Thus to reduce the impact of noise, we use the CS loss
 78 \mathcal{L}_{cs} to train our model. In contrast, the qualitative results of using \mathcal{L}_{cs} are shown in the second row
 79 of Figure 3. We can see that the proposed CS significantly reduces the impact of randomness and
 80 subjectivity, and produces reasonable predictions by our method.

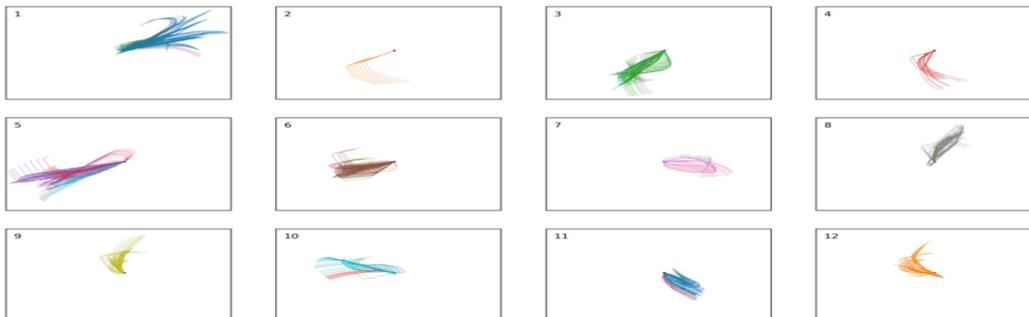


Figure 1: Visualization of clustered trajectories (12 clusters). Each group trajectory is the average of the trajectories belonging to the same cluster.

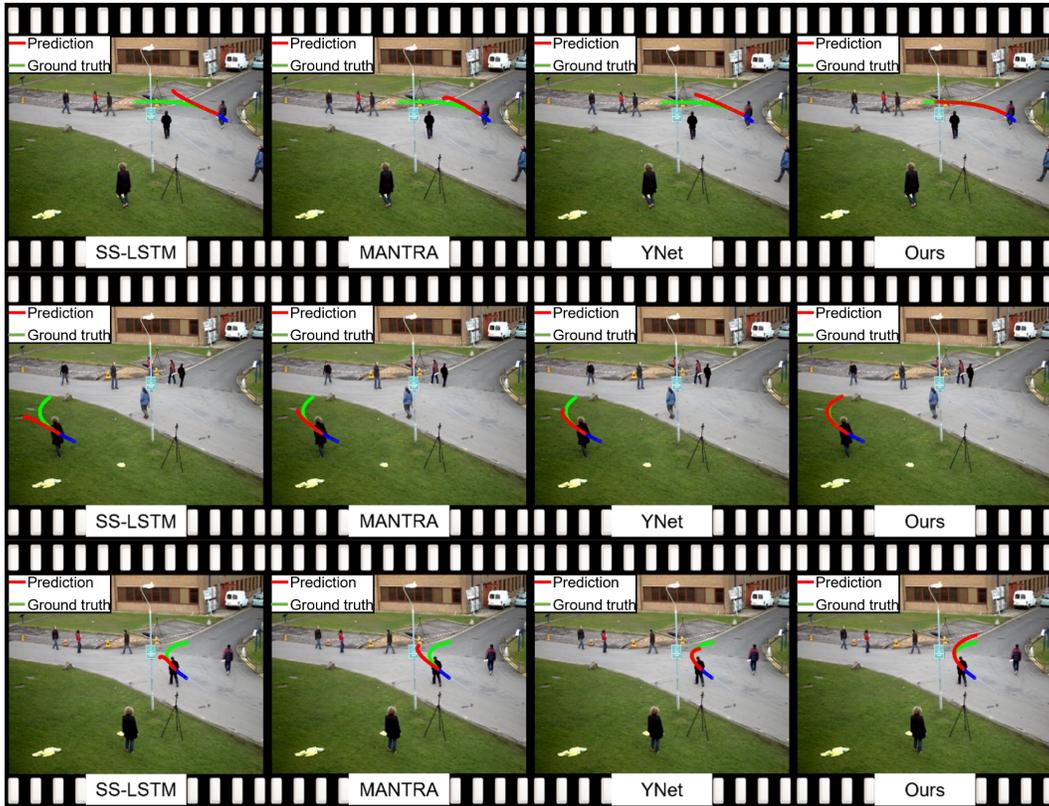
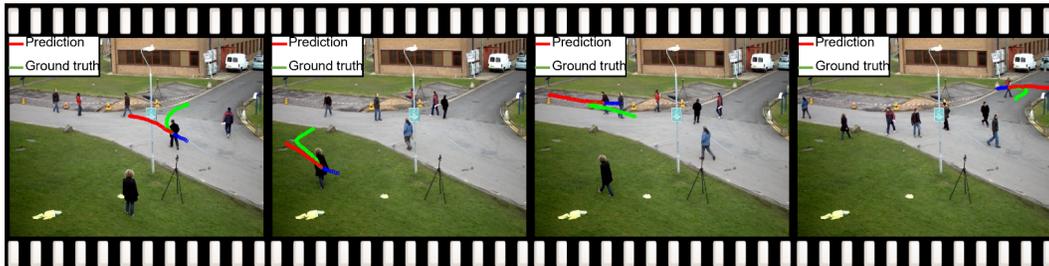


Figure 2: Qualitative visualization of our method and state-of-the-art methods. The blue line is the observed trajectory. The red and green lines show the predicted and ground truth trajectories.



(a) Results of using \mathcal{L}_{tra} .



(b) Results of using \mathcal{L}_{cs} .

Figure 3: Qualitative visualization of our SHENet without/with CS. The results of using \mathcal{L}_{tra} give a wrong destination, while the results of using \mathcal{L}_{cs} produce reasonable predictions.