Learning Reconstruction-based Remote Gaze Estimation Supplementary Material

Pei Yu, Jiahuan Zhou and Ying Wu
Northwestern University
2145 Sheridan Road, Evanston IL, 60208
{pyi980, jzt011, yingwu}@eecs.northwestern.edu

1. Experimental result with fixed-pose and fixed-subject setting

This section provides detailed experimental result on UT multi-view gaze dataset, with fixed-pose and fixed-subject setting. For each subject, average estimation error in degree, standard deviation of error, and p value are provided, where p value is calculated by performing Wilcoxon signed rank test between one baseline method and *Ours-R*. A p value less than 0.05 indicates that the estimation error by *Ours-R* is statistically significantly different to the estimation error by one baseline method.

The detailed experimental result with 30-D appearance feature is presented in table 1 and table 2. The detailed experimental result with 64-D appearance feature is presented in table 3 and table 4. Estimation error is presented in the form of $mean \pm std$. The best estimation error is marked by bold face, while the second best one is in blue color. p value smaller than 0.05 is marked by bold face.

With 30-D appearance feature, out of total 50 experiment subjects, *Ours-R* achieves the lowest and second lowest average estimation error for 44 and 3 subjects, respectively. *Ours* achieves the lowest and second lowest average estimation error for 4 and 23 subjects, respectively. Compared with ALR, LLR-TRI, LLR, SVR and k-NN, the estimation error of *Ours-R* is significantly different for 24, 22, 14, 40 and 50 subjects, respectively.

With 64-D appearance feature, out of total 50 experiment subjects, *Ours-R* achieves the lowest and second lowest average estimation error for 37 and 12 subjects, respectively. *Ours* achieves the lowest and second lowest average estimation error for 8 and 24 subjects, respectively. Compared with ALR, LLR-TRI, LLR, SVR and k-NN, the estimation error of *Ours-R* is significantly different for 20, 28, 33, 22 and 50 subjects, respectively.

2. The relationship between estimation error and the distance between training and testing poses

This section investigates under cross-pose setting, how the estimation error changes w.r.t. the distance between training and testing poses. This experiment is conducted on UT multi-view gaze dataset as in Sec. 4.2.4. in main submission. We use synthesized images of each subject for training, and actual recorded images of the same subject for testing.

For each testing pose of one subject, we divide all training poses into different subsets w.r.t. the distance between testing pose and training pose. In each subset, the variation of the distance between testing and training poses is 5 degree, *i.e.* $n^\circ \leq |\mathbf{p}' - \mathbf{p}| \leq n^\circ + 5^\circ$, where $\mathbf{p}'$ denotes the head pose of the query appearance, $\mathbf{p}$ denotes the training pose. We divide the distance between poses, from 0° to 50°, into bins with length of 5°, *i.e.* there are in total 10 subsets of the training set, in each of which the distance between training and testing pose is $n^\circ \leq |\mathbf{p}' - \mathbf{p}| \leq n^\circ + 5^\circ$, $n = \{0, 5, \ldots, 45\}$. Other settings are the same as in Sec. 4.2.4. in main submission. All of 160 gaze positions are included in training and testing with no split. k for k-NN is set to 10. The appearance feature is extracted from single eye with 9×15 dimension.

The result is shown in Fig 1. Our proposed method *Ours-R* achieves the best performance. Moreover, as the distance between testing pose and training pose increases, our proposed method still achieves the lowest estimation error.

3. Experiment on video

An experiment was performed on a video. In this video, a user was asked to move the cursor of mouse with an arbitrary path. While moving the cursor, the user was asked to keep eyes focused on the tip of the cursor, which gave the ground truth. Our proposed gaze estimation methods and baseline methods were evaluated on this video.

Subject		k-NN	SVR	LLR	LLR-TRI	ALR	Ours	Ours-R
Subject 00	Error	2.91±2.02	2.11±1.75	1.60±1.68	1.71±1.58	1.55±1.13	**1.44±1.38**	**1.44±1.38**
	p-value	**0.0000**	**0.0000**	0.2266	**0.0012**	0.3234	1.0000	-
Subject 01	Error	2.46±2.08	1.57±2.00	1.37±1.69	1.33±1.85	1.54±2.55	1.28±1.44	**1.25±1.44**
	p-value	**0.0000**	**0.0137**	0.2411	0.5613	0.0631	0.1027	-
Subject 02	Error	2.28±1.52	1.02±1.08	0.90±1.41	0.98±1.56	0.81±0.74	0.86±0.98	**0.79±0.97**
	p-value	**0.0000**	**0.0000**	0.3665	0.1218	0.5975	**0.0390**	-
Subject 03	Error	2.41±1.45	1.53±1.17	1.44±0.82	1.39±0.78	1.37±0.99	1.39±0.89	**1.30±0.86**
	p-value	**0.0000**	0.0787	0.1193	0.2369	0.2652	0.0661	-
Subject 04	Error	1.88±1.22	0.90±0.54	0.83±0.50	0.76±0.48	1.14±0.70	0.78±0.44	**0.76±0.41**
	p-value	**0.0000**	**0.0011**	0.4131	0.9958	**0.0001**	0.3722	-
Subject 05	Error	2.88±1.55	2.20±1.12	1.46±0.92	1.39±0.84	1.48±0.88	1.33±0.85	**1.28±0.77**
	p-value	**0.0000**	**0.0000**	0.0734	0.2885	**0.0180**	0.4283	-
Subject 06	Error	2.19±1.44	0.93±0.59	0.82±0.42	0.78±0.43	0.87±0.52	0.69±0.41	**0.68±0.39**
	p-value	**0.0000**	**0.0000**	**0.0019**	**0.0165**	**0.0005**	0.9327	-
Subject 07	Error	3.16±1.73	1.49±1.00	1.56±1.08	1.67±1.09	1.50±1.19	1.39±0.92	**1.31±0.82**
	p-value	**0.0000**	**0.0395**	**0.0118**	**0.0001**	0.1310	**0.0129**	-
Subject 08	Error	2.11±1.61	1.03±0.60	0.97±0.68	**0.88±0.61**	1.10±0.68	0.98±0.59	0.97±0.60
	p-value	**0.0000**	0.2958	0.8950	0.0653	0.0796	0.7675	-
Subject 09	Error	2.63±1.75	1.31±1.16	1.37±1.66	1.42±1.80	1.23±1.18	1.30±1.41	**1.18±1.39**
	p-value	**0.0000**	**0.0229**	0.0941	0.0805	0.1270	**0.0196**	-
Subject 10	Error	2.72±1.94	1.61±2.55	1.60±2.38	1.58±2.70	1.67±3.14	1.44±2.33	**1.38±2.57**
	p-value	**0.0000**	**0.0026**	**0.0149**	**0.0133**	**0.0001**	0.0653	-
Subject 11	Error	2.74±2.86	1.58±2.32	1.49±1.93	1.69±2.63	1.56±2.64	1.50±2.28	**1.41±2.28**
	p-value	**0.0000**	**0.0154**	0.4283	**0.0170**	**0.0333**	**0.0448**	-
Subject 12	Error	2.63±1.78	1.26±0.87	1.07±0.88	1.02±0.73	1.36±0.90	1.00±0.85	**1.00±0.83**
	p-value	**0.0000**	**0.0034**	0.2837	0.8163	**0.0005**	0.6422	-
Subject 13	Error	2.77±1.61	1.18±0.80	1.08±0.73	1.26±0.96	1.07±0.72	0.96±0.73	**0.95±0.72**
	p-value	**0.0000**	**0.0133**	0.0601	**0.0019**	0.0580	0.8327	-
Subject 14	Error	2.55±1.55	**1.03±0.59**	1.26±0.80	1.34±0.79	1.06±0.62	1.15±0.71	1.09±0.69
	p-value	**0.0000**	0.7195	**0.0465**	**0.0040**	0.7275	0.2286	-
Subject 15	Error	3.55±3.41	2.33±3.05	2.74±3.93	2.86±4.99	2.58±4.13	2.36±3.36	**2.30±3.30**
	p-value	**0.0000**	0.4759	**0.0304**	0.7038	0.2050	0.4407	-
Subject 16	Error	2.11±1.38	1.14±0.70	1.12±0.71	1.07±0.63	1.07±0.60	1.01±0.64	**0.92±0.57**
	p-value	**0.0000**	**0.0019**	**0.0055**	**0.0147**	**0.0288**	**0.0210**	-
Subject 17	Error	2.88±2.66	1.47±1.94	1.57±2.46	1.77±3.13	1.38±2.00	1.28±1.55	**1.25±1.59**
	p-value	**0.0000**	**0.0400**	**0.0127**	**0.0121**	0.2369	0.5938	-
Subject 18	Error	1.97±1.15	1.00±0.60	0.78±0.55	0.89±0.55	0.87±0.59	0.78±0.48	**0.77±0.48**
	p-value	**0.0000**	**0.0012**	0.9958	**0.0139**	0.1108	0.9537	-
Subject 19	Error	2.48±1.77	1.12±0.65	1.23±0.73	1.20±0.75	1.04±0.58	1.09±0.72	**1.02±0.55**
	p-value	**0.0000**	**0.0459**	**0.0448**	0.1039	0.7958	0.5793	-
Subject 20	Error	1.99±1.25	0.87±0.53	0.74±0.51	0.72±0.45	0.98±0.60	0.72±0.43	**0.70±0.42**
	p-value	**0.0000**	**0.0020**	0.5902	0.6497	**0.0001**	0.2390	-
Subject 21	Error	2.01±1.26	1.01±0.65	0.72±0.48	0.76±0.46	0.92±0.60	0.70±0.39	**0.69±0.38**
	p-value	**0.0000**	**0.0001**	0.6921	0.1698	**0.0007**	0.7715	-
Subject 22	Error	2.35±1.63	0.89±0.76	0.66±0.42	0.71±0.39	0.73±0.50	0.62±0.37	**0.60±0.40**
	p-value	**0.0000**	**0.0011**	0.1570	**0.0029**	**0.0016**	**0.0133**	-
Subject 23	Error	2.21±1.70	0.89±0.58	0.93±0.74	0.89±0.55	0.88±0.53	0.79±0.53	**0.75±0.49**
	p-value	**0.0000**	**0.0238**	**0.0175**	**0.0108**	**0.0071**	0.0526	-
Subject 24	Error	3.02±1.95	1.23±0.75	1.36±1.08	1.37±0.98	1.12±0.73	1.11±0.87	**1.00±0.80**
	p-value	**0.0000**	**0.0005**	**0.0001**	**0.0000**	0.0580	**0.0066**	-
Subject 25	Error	2.00±1.39	1.05±0.65	0.89±0.57	0.82±0.52	0.98±0.54	0.85±0.38	**0.81±0.42**
	p-value	**0.0000**	**0.0006**	0.5058	0.8825	**0.0048**	**0.0454**	-

Table 1. Experimental result on UT dataset with 30-D feature, subject 00-25.

In the estimation result of this video, the red circle denotes the mouse cursor, the yellow plus denotes the estimation result of k-NN, the magenta plus denotes the estimation result of SVR, the black plus denotes the estimation result of LLR, the cyan plus denotes the estimation result of LLR_TRI, the green plus denotes the estimation result of ALR, the red plus denotes the estimation result of *Ours*, the blue plus denotes the estimation result of *Ours-R*.

As shown in this video, in the early stage of estimation, our proposed methods get more reliable and more stable result than other baseline methods since the head pose variation is small. It is shown that *Ours-R* has improved gaze estimation accuracy compared with *Ours*. As the cursor moves, the user's head moves slowly, which introduces head pose variation deviated from

Subject		k-NN	SVR	LLR	LLR-TRI	ALR	Ours	Ours-R
Subject 26	Error	2.76±2.43	1.49±1.10	1.28±1.20	1.47±1.46	1.19±1.17	1.23±1.08	**1.13±1.02**
	p-value	**0.0000**	**0.0000**	0.2266	**0.0031**	0.6159	**0.0266**	-
Subject 27	Error	2.65±1.43	1.15±0.61	1.00±0.63	1.04±0.69	0.91±0.54	0.83±0.57	**0.80±0.53**
	p-value	**0.0000**	**0.0000**	**0.0001**	**0.0007**	**0.0329**	0.1005	-
Subject 28	Error	1.96±1.35	1.03±0.73	0.87±0.65	0.86±0.64	1.10±0.81	0.82±0.59	**0.79±0.58**
	p-value	**0.0000**	**0.0016**	0.2607	0.2108	**0.0001**	0.0594	-
Subject 29	Error	3.04±1.94	1.82±1.10	1.62±1.28	1.81±1.45	1.68±1.39	1.65±1.26	**1.55±1.25**
	p-value	**0.0000**	**0.0027**	0.8122	0.0787	0.2088	**0.0185**	-
Subject 30	Error	2.86±2.30	1.58±1.38	1.48±1.83	1.41±1.44	1.26±1.24	1.20±1.41	**1.18±1.40**
	p-value	**0.0000**	**0.0003**	**0.0071**	**0.0160**	0.4041	0.2607	-
Subject 31	Error	2.18±1.42	1.19±0.84	1.03±0.79	0.96±0.73	1.05±0.72	0.93±0.68	**0.86±0.64**
	p-value	**0.0000**	**0.0001**	**0.0101**	0.0653	**0.0010**	**0.0375**	-
Subject 32	Error	2.39±1.81	1.08±0.63	0.88±1.07	0.87±0.55	1.06±0.86	0.87±0.91	**0.85±0.90**
	p-value	**0.0000**	**0.0010**	0.4759	0.3234	**0.0090**	0.1617	-
Subject 33	Error	1.95±1.33	0.85±0.43	0.91±0.50	0.85±0.46	0.92±0.52	0.85±0.47	**0.77±0.38**
	p-value	**0.0000**	0.0608	0.0559	0.1244	**0.0037**	0.0871	-
Subject 34	Error	2.12±1.43	1.21±0.84	1.20±0.85	1.20±0.89	1.20±0.77	1.27±0.80	**1.11±0.75**
	p-value	**0.0000**	0.0861	0.4597	0.4597	**0.0380**	**0.0375**	-
Subject 35	Error	2.34±1.56	1.15±0.88	0.92±0.70	0.92±0.57	1.05±0.77	**0.80±0.52**	**0.80±0.52**
	p-value	**0.0000**	**0.0002**	0.1016	**0.0415**	**0.0022**	1.0000	-
Subject 36	Error	2.37±1.67	1.51±1.23	1.18±0.71	1.25±0.78	1.43±1.33	**1.14±0.70**	**1.14±0.70**
	p-value	**0.0000**	**0.0006**	0.9958	0.0787	**0.0131**	1.0000	-
Subject 37	Error	2.02±1.48	0.78±0.55	0.69±0.43	0.70±0.47	0.73±0.50	0.66±0.44	**0.65±0.44**
	p-value	**0.0000**	**0.0292**	0.0973	0.6122	**0.0442**	0.5902	-
Subject 38	Error	2.30±1.44	1.07±0.81	0.95±0.70	0.93±0.74	0.97±0.62	**0.88±0.69**	**0.88±0.69**
	p-value	**0.0000**	**0.0277**	0.3982	0.8992	0.0669	0.2123	-
Subject 39	Error	2.63±1.53	1.08±0.60	1.17±0.98	1.19±0.81	0.97±0.60	1.08±0.78	**0.96±0.60**
	p-value	**0.0000**	**0.0006**	0.1379	**0.0083**	0.9663	0.2675	-
Subject 40	Error	2.60±1.75	1.70±1.10	1.66±1.29	1.56±1.28	1.61±1.00	1.63±0.87	**1.41±0.81**
	p-value	**0.0000**	**0.0111**	0.0594	0.4891	**0.0400**	**0.0058**	-
Subject 41	Error	2.91±1.58	1.46±1.12	1.58±1.10	1.86±1.20	**1.45±0.93**	1.51±0.99	1.47±1.07
	p-value	**0.0000**	0.4727	0.7999	**0.0080**	0.6048	0.6727	-
Subject 42	Error	2.67±1.47	1.33±0.93	1.16±0.73	1.25±0.85	1.24±0.81	1.14±0.79	**1.10±0.70**
	p-value	**0.0000**	**0.0329**	0.1886	0.1524	0.0931	0.5092	-
Subject 43	Error	3.56±3.26	**1.88±2.15**	2.45±2.61	2.53±3.23	2.12±2.47	2.35±2.34	1.91±1.77
	p-value	**0.0000**	0.2266	0.1096	0.1698	0.2390	0.1323	-
Subject 44	Error	2.21±1.39	1.22±1.01	1.02±0.74	1.00±0.88	1.35±0.99	**0.95±0.70**	**0.95±0.70**
	p-value	**0.0000**	**0.0047**	0.1039	0.2933	**0.0000**	1.0000	-
Subject 45	Error	2.77±2.51	1.84±1.49	1.86±2.39	2.05±3.10	1.71±1.62	1.67±2.15	**1.57±1.93**
	p-value	**0.0000**	**0.0320**	0.1798	0.1257	0.1555	0.0760	-
Subject 46	Error	1.95±1.16	0.82±0.61	0.89±0.54	0.91±0.49	0.84±0.53	0.80±0.55	**0.75±0.52**
	p-value	**0.0000**	0.1393	**0.0039**	**0.0045**	**0.0219**	**0.0390**	-
Subject 47	Error	2.90±2.06	1.63±1.88	1.22±0.73	1.63±2.29	1.14±1.03	1.18±0.83	**1.14±0.84**
	p-value	**0.0000**	**0.0025**	0.2861	**0.0120**	0.1586	0.4891	-
Subject 48	Error	2.73±1.77	1.93±3.22	**1.71±1.23**	2.04±2.81	1.72±2.07	1.74±1.68	1.71±1.65
	p-value	**0.0000**	0.6960	0.3183	**0.0410**	0.6535	0.8368	-
Subject 49	Error	1.98±1.32	1.52±0.88	**1.01±0.72**	1.10±0.72	1.03±0.67	1.10±0.64	1.04±0.64
	p-value	**0.0000**	**0.0000**	0.6048	0.4470	0.9327	0.0718	-
Average	Error	2.49±1.84	1.32±1.32	1.23±1.34	1.27±1.60	1.23±1.35	1.14±1.20	**1.08±1.15**
	p-value	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0000**	-

Table 2. Experimental result on UT dataset with 30-D feature, subject 26-49 and average.

the head pose of training stage. Because of the error caused by accumulated head pose variation, the estimation results of all methods are deviating from the ground truth.

Subject		k-NN	SVR	LLR	LLR-TRI	ALR	Ours	Ours-R
Subject 00	Error	2.91±1.96	1.37±1.10	1.45±1.54	1.53±1.58	1.25±1.00	1.26±1.11	**1.24±1.14**
	p-value	**0.0000**	**0.0448**	0.0743	**0.0123**	0.6271	0.2909	-
Subject 01	Error	2.37±1.72	1.17±2.45	1.18±1.48	1.05±1.10	1.38±3.89	**1.03±2.20**	1.03±2.22
	p-value	**0.0000**	**0.0097**	**0.0028**	**0.0380**	**0.0033**	0.4891	-
Subject 02	Error	2.18±1.56	0.90±1.13	0.87±1.47	0.93±1.61	**0.68±0.55**	0.69±1.06	0.68±1.05
	p-value	**0.0000**	**0.0000**	**0.0087**	**0.0001**	**0.0477**	0.3445	-
Subject 03	Error	2.53±1.47	1.30±0.85	1.35±0.79	1.32±0.78	1.28±0.90	1.26±0.81	**1.21±0.75**
	p-value	**0.0000**	0.1296	0.0994	0.0587	0.2885	0.4314	-
Subject 04	Error	1.86±1.18	0.68±0.45	0.71±0.43	0.65±0.40	1.14±0.69	**0.63±0.35**	**0.63±0.35**
	p-value	**0.0000**	0.2245	**0.0083**	0.4858	**0.0000**	0.5757	-
Subject 05	Error	2.91±1.49	1.17±0.75	1.22±0.83	1.14±0.81	1.23±0.91	1.14±0.69	**1.09±0.70**
	p-value	**0.0000**	0.0520	0.1994	0.9075	**0.0175**	0.2327	-
Subject 06	Error	2.20±1.40	0.73±0.50	0.69±0.37	0.67±0.37	0.75±0.44	**0.57±0.36**	**0.57±0.36**
	p-value	**0.0000**	**0.0020**	**0.0097**	0.0526	**0.0002**	0.9285	-
Subject 07	Error	3.05±1.77	**1.10±0.79**	1.54±1.14	1.62±1.16	1.32±1.07	1.16±0.72	1.12±0.69
	p-value	**0.0000**	0.6727	**0.0003**	**0.0000**	**0.0145**	0.2127	-
Subject 08	Error	2.09±1.62	0.90±0.59	0.90±0.64	0.85±0.54	0.82±0.55	0.81±0.47	**0.77±0.45**
	p-value	**0.0000**	0.0994	**0.0459**	0.3312	0.2790	0.1816	-
Subject 09	Error	2.58±1.89	1.07±0.76	1.29±1.69	1.21±1.16	**0.85±0.73**	0.91±1.01	0.87±0.93
	p-value	**0.0000**	**0.0005**	**0.0001**	**0.0012**	1.0000	0.2432	-
Subject 10	Error	2.67±1.80	1.28±2.49	1.37±1.49	1.43±2.29	1.51±3.54	**1.21±1.90**	1.21±1.97
	p-value	**0.0000**	0.5472	**0.0225**	**0.0106**	**0.0229**	0.0701	-
Subject 11	Error	2.68±2.62	1.42±2.34	1.40±2.06	1.51±2.34	1.63±4.45	1.25±2.15	**1.23±2.18**
	p-value	**0.0000**	**0.0094**	**0.0114**	**0.0001**	0.0677	0.4534	-
Subject 12	Error	2.63±1.66	0.92±0.61	0.90±0.63	0.89±0.68	0.91±0.62	**0.80±0.73**	**0.80±0.73**
	p-value	**0.0000**	**0.0325**	**0.0431**	0.1296	**0.0308**	1.0000	-
Subject 13	Error	2.73±1.62	0.81±0.50	0.97±0.66	1.01±0.77	**0.69±0.38**	0.70±0.49	0.69±0.50
	p-value	**0.0000**	0.0752	**0.0001**	**0.0003**	0.9621	0.4161	-
Subject 14	Error	2.50±1.54	**0.74±0.46**	1.09±0.80	1.19±0.69	0.77±0.43	0.88±0.53	0.82±0.50
	p-value	**0.0000**	0.1180	**0.0069**	**0.0000**	0.1494	**0.0375**	-
Subject 15	Error	3.42±3.28	2.22±3.24	2.43±3.38	2.68±4.72	2.84±3.55	2.14±3.05	**2.05±3.11**
	p-value	**0.0000**	0.5263	**0.0034**	0.4565	**0.0000**	**0.0495**	-
Subject 16	Error	2.10±1.36	0.82±0.56	1.05±0.62	1.04±0.60	0.88±0.65	0.85±0.60	**0.78±0.53**
	p-value	**0.0000**	0.1903	**0.0001**	**0.0000**	**0.0351**	**0.0292**	-
Subject 17	Error	2.96±2.73	1.24±1.38	1.58±2.75	1.67±3.65	**1.05±1.33**	1.10±1.66	1.10±1.64
	p-value	**0.0000**	**0.0014**	**0.0008**	**0.0347**	0.9369	0.7195	-
Subject 18	Error	2.04±1.10	0.75±0.48	0.73±0.48	0.78±0.47	0.73±0.54	**0.62±0.43**	**0.62±0.43**
	p-value	**0.0000**	**0.0079**	**0.0028**	**0.0002**	**0.0347**	0.6999	-
Subject 19	Error	2.37±1.65	**0.82±0.44**	1.15±0.79	1.00±0.66	0.96±0.66	0.87±0.49	0.86±0.45
	p-value	**0.0000**	0.3081	**0.0015**	0.1193	0.2327	0.3106	-
Subject 20	Error	1.88±1.33	0.65±0.34	0.68±0.39	0.71±0.42	0.84±0.48	0.59±0.32	**0.58±0.32**
	p-value	**0.0000**	**0.0048**	**0.0284**	**0.0058**	**0.0000**	0.2475	-
Subject 21	Error	2.05±1.30	0.68±0.48	0.62±0.34	0.65±0.33	0.72±0.44	**0.61±0.28**	**0.61±0.28**
	p-value	**0.0000**	0.1976	0.3365	0.0973	0.0718	0.5721	-
Subject 22	Error	2.22±1.40	0.71±0.59	0.65±0.40	0.66±0.41	0.64±0.42	0.60±0.39	**0.59±0.41**
	p-value	**0.0000**	**0.0077**	0.2032	0.1509	0.1323	0.2475	-
Subject 23	Error	2.16±1.68	0.82±0.55	0.82±0.71	0.71±0.48	0.71±0.51	0.67±0.46	**0.65±0.47**
	p-value	**0.0000**	**0.0004**	**0.0210**	0.2088	0.0653	0.0891	-
Subject 24	Error	2.94±1.89	0.99±0.73	1.38±1.13	1.24±0.93	1.06±0.85	0.95±0.77	**0.92±0.75**
	p-value	**0.0000**	0.1781	**0.0000**	**0.0006**	**0.0125**	0.1524	-
Subject 25	Error	2.08±1.41	0.85±0.53	0.80±0.58	0.75±0.49	0.77±0.58	**0.68±0.40**	**0.68±0.40**
	p-value	**0.0000**	**0.0031**	0.0752	0.0941	0.0646	0.7117	-

Table 3. Experimental result on UT dataset with 64-D feature, subject 00-25.

Subject		k-NN	SVR	LLR	LLR-TRI	ALR	Ours	Ours-R
Subject 26	Error	2.78±2.35	1.27±0.97	1.12±1.19	1.31±1.54	1.10±0.96	1.10±0.88	**1.01±0.87**
	p-value	**0.0000**	**0.0008**	0.7038	0.0921	0.1665	**0.0103**	-
Subject 27	Error	2.60±1.53	0.87±0.55	0.90±0.62	0.85±0.63	0.79±0.43	0.62±0.38	**0.60±0.38**
	p-value	**0.0000**	**0.0003**	**0.0000**	**0.0002**	**0.0002**	0.1450	-
Subject 28	Error	1.93±1.26	0.69±0.51	0.77±0.51	0.70±0.43	0.72±0.49	0.57±0.36	**0.56±0.38**
	p-value	**0.0000**	**0.0006**	**0.0001**	**0.0013**	**0.0001**	0.1958	-
Subject 29	Error	3.00±1.88	1.33±1.01	1.54±1.18	1.73±1.36	1.41±1.37	1.28±1.08	**1.24±1.06**
	p-value	**0.0000**	0.1283	**0.0070**	**0.0000**	**0.0193**	0.3157	-
Subject 30	Error	2.73±2.32	0.94±1.02	1.36±1.53	1.30±1.61	0.98±0.92	0.97±0.97	**0.93±0.98**
	p-value	**0.0000**	0.9243	**0.0002**	**0.0003**	0.2861	0.1407	-
Subject 31	Error	2.12±1.34	1.02±0.66	0.93±0.82	0.90±0.72	0.99±0.62	0.77±0.57	**0.74±0.52**
	p-value	**0.0000**	**0.0000**	**0.0092**	**0.0210**	**0.0000**	0.4191	-
Subject 32	Error	2.41±1.93	0.86±0.55	0.81±0.73	0.78±0.73	**0.72±0.46**	0.76±0.62	0.76±0.62
	p-value	**0.0000**	0.1764	**0.0471**	0.6196	0.8410	1.0000	-
Subject 33	Error	1.99±1.29	**0.62±0.33**	0.80±0.47	0.73±0.39	0.73±0.40	0.66±0.36	0.65±0.33
	p-value	**0.0000**	0.2909	0.0891	0.2540	**0.0098**	0.4071	-
Subject 34	Error	2.17±1.42	1.00±0.75	1.14±0.86	1.10±0.88	1.14±0.91	0.99±0.76	**0.96±0.72**
	p-value	**0.0000**	0.3208	**0.0120**	0.0823	0.0743	0.2266	-
Subject 35	Error	2.30±1.55	0.98±0.85	0.88±0.64	0.83±0.51	0.94±0.75	**0.82±0.54**	**0.82±0.54**
	p-value	**0.0000**	**0.0238**	0.2369	0.9579	0.0653	1.0000	-
Subject 36	Error	2.33±1.47	1.10±0.83	**1.05±0.66**	1.17±0.79	1.17±0.98	1.07±0.79	1.07±0.80
	p-value	**0.0000**	0.4858	0.3637	**0.0442**	0.1296	0.6689	-
Subject 37	Error	1.97±1.45	0.60±0.46	0.65±0.39	0.65±0.43	**0.56±0.42**	0.61±0.40	**0.56±0.42**
	p-value	**0.0000**	**0.0238**	**0.0046**	**0.0316**	0.3554	**0.0074**	-
Subject 38	Error	2.41±1.50	0.90±0.64	0.83±0.64	**0.79±0.60**	0.85±0.61	0.80±0.60	**0.79±0.60**
	p-value	**0.0000**	0.0553	0.5332	0.7958	0.1257	0.4630	-
Subject 39	Error	2.58±1.50	0.79±0.48	1.01±0.75	1.03±0.69	0.84±0.82	0.75±0.45	**0.73±0.47**
	p-value	**0.0000**	0.3056	**0.0008**	**0.0000**	0.7394	0.1833	-
Subject 40	Error	2.53±1.59	**0.97±0.52**	1.41±1.13	1.28±0.83	0.99±0.64	1.02±0.56	0.97±0.56
	p-value	**0.0000**	0.7077	**0.0004**	**0.0026**	0.4470	0.0718	-
Subject 41	Error	2.98±1.61	1.39±0.92	**1.31±0.83**	1.69±1.17	1.44±1.36	1.36±0.82	1.36±0.82
	p-value	**0.0000**	0.8204	0.5263	**0.0036**	0.8700	1.0000	-
Subject 42	Error	2.71±1.48	1.05±0.66	1.09±0.75	1.07±0.81	0.99±0.63	0.97±0.70	**0.94±0.64**
	p-value	**0.0000**	**0.0316**	**0.0489**	**0.0219**	0.2432	0.1509	-
Subject 43	Error	3.53±3.23	1.96±2.52	2.31±2.72	2.44±3.30	2.02±3.70	2.03±2.52	**1.84±2.31**
	p-value	**0.0000**	0.6804	0.0994	0.0962	0.4071	0.1539	-
Subject 44	Error	2.17±1.36	0.93±0.80	0.92±0.64	0.86±0.76	0.98±0.98	0.84±0.64	**0.83±0.64**
	p-value	**0.0000**	0.0796	0.0984	0.9075	0.0743	0.8327	-
Subject 45	Error	2.79±2.41	1.75±3.00	1.68±1.84	1.81±3.00	1.59±2.80	1.53±2.20	**1.39±2.04**
	p-value	**0.0000**	**0.0090**	**0.0017**	**0.0008**	**0.0059**	**0.0459**	-
Subject 46	Error	1.98±1.20	0.64±0.42	0.78±0.44	0.84±0.52	0.64±0.42	0.65±0.44	**0.60±0.46**
	p-value	**0.0000**	0.0709	**0.0001**	**0.0001**	0.0911	**0.0312**	-
Subject 47	Error	2.85±2.06	1.35±2.28	1.03±0.68	1.49±2.64	1.17±1.24	1.03±0.72	**0.94±0.68**
	p-value	**0.0000**	0.1494	0.4924	**0.0193**	**0.0095**	**0.0454**	-
Subject 48	Error	2.59±1.77	1.74±1.89	1.67±1.30	1.72±2.21	2.06±6.24	**1.55±1.31**	**1.55±1.31**
	p-value	**0.0000**	0.4502	0.5865	0.4345	0.3807	0.8245	-
Subject 49	Error	2.01±1.32	1.42±0.85	0.94±0.66	0.93±0.58	0.94±0.57	0.91±0.51	**0.89±0.51**
	p-value	**0.0000**	**0.0000**	0.5685	0.6011	0.2475	0.4283	-
Average	Error	2.47±1.80	1.05±1.26	1.11±1.24	1.14±1.53	1.06±1.75	0.95±1.10	**0.92±1.08**
	p-value	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0000**	-

Table 4. Experimental result on UT dataset with 64-D feature, subject 26-49 and average.

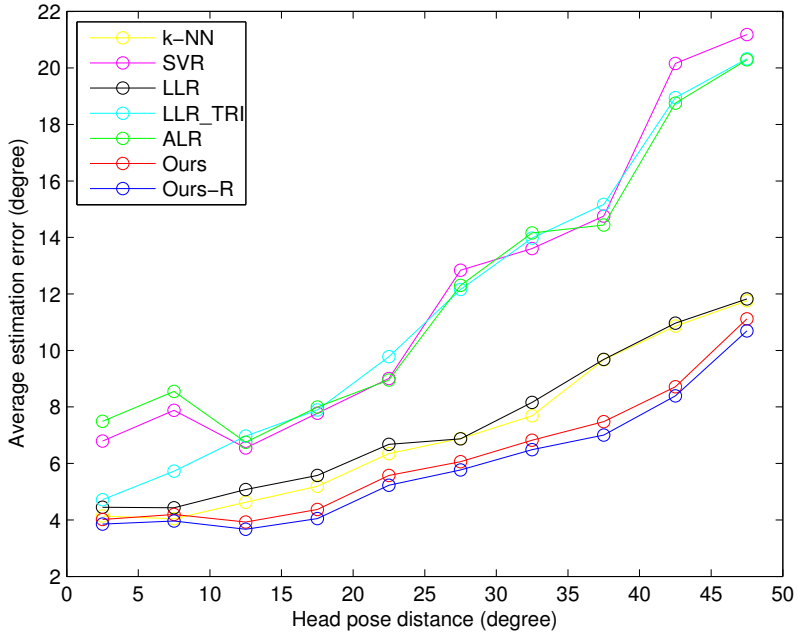

Figure 1. Illustration of the relationship between average estimation error and the distance between training and testing poses.