BK 장기연수 결과보고서

연수기간	2022.09.15 . ~ 2022.10.26. (41 일간)
연수기관	Friedrich-Alexander-Universität Erlangen-Nürnberg
연구주제	Develop AI-based CBCT image motion compensation technology

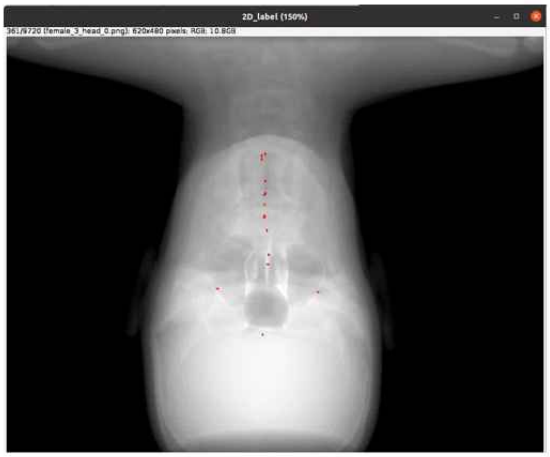
1. 연수활동 내용

연수목적	1) Cooperate the research with the team from the Pattern Recognition unit of FAU to develop AI-based CBCT image motion compensation technology, 2) Workshop on AI-based healthcare data processing and discussion on the direction of collaboration between by the BK21 Four System Health Science & Engineering program at EWHA and the Pattern Recognition unit of FAU.
연수내용	To develop the deep learning model for the CBCT image motion compensation, the cephalometric landmark of the human head from 2D-space image in multiview are detected with the deep learning model. Then, the detected landmark from all of the view is projected to 3d to calculated the mean average position as a reference position of the human. After that, each 3D reference landmark is projected back to 2D space, and the difference position between the detected landmark and reference point in 2D space is used to compensate the motion of the human during taking the CT scan.
결과 및 시사점	The head phatom dataset is prepared by labeling 16 cephalometric landmarks on 19 patients. The dataset is divided to training and testing dataset for landmark detection deep learning model. We tested the benchmark detection model based on convolutional neural network (CNN) and transformer network. The HRNet – w32, which is the CNN based model, acheived the best accuracy with 5.2958±7.4726 mm MRE. Then, we used the landmark information that are detected from detection deep learning model to do the motion compensation. Furthermore, we perform the motion compensation with varies scenarios of landmark information, and achieve the best images quality with 0.66656 SSIM, 28.82544 PSNR, 9.43386 RMSE.
향후 연구에 대한 적용방안	We plan to develop practical deep learning model for CBCT motion compentation to enhance the 3D CT scan quality by reducing the noise from the human motion.

2. 일자별 활동내역(사진 첨부하여 구체적으로 기술 요망)

2022.09.15 - 2022.09.23

- Confirm the correctness of all 16 cephalometric landmarks of all 19 patients in both 2D and 3D space.
- Found the problem on 2D projection images, i.e., 16 patients with missing landmark and 3 patients with wrong position landmark problems, and summarized all of the problem of each patient.

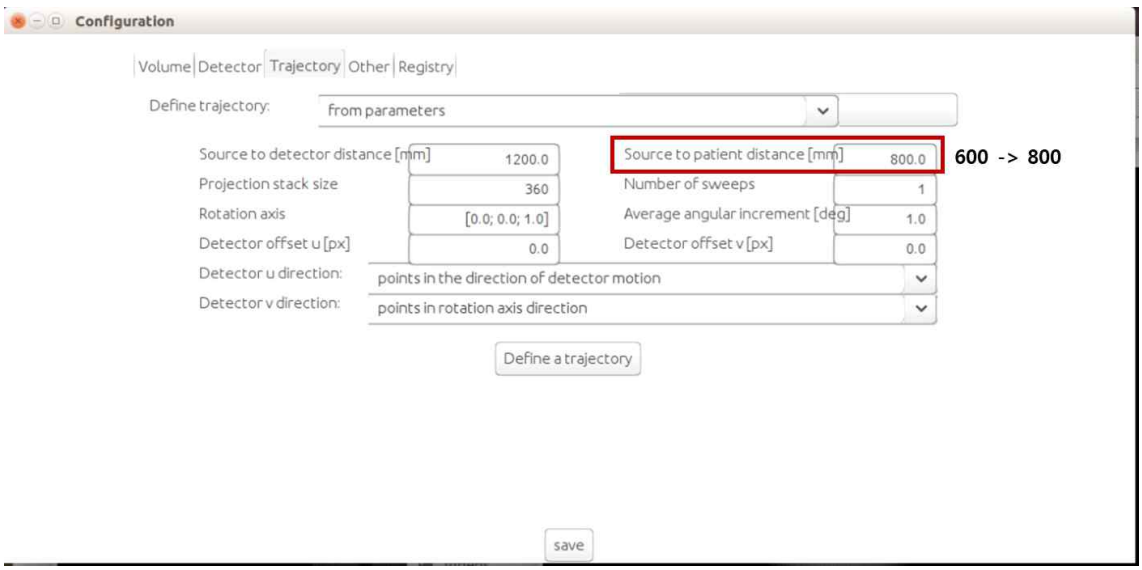


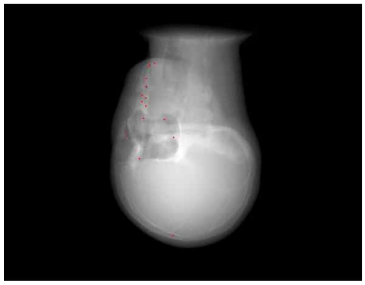
Missing landmark

Wrong position landmark

2022.09.26 - 2022.09.30

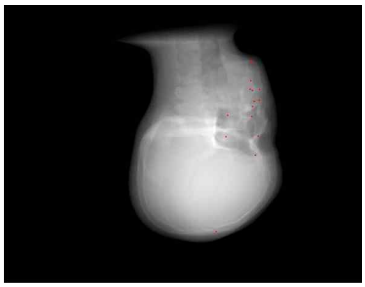
- Solve the missing landmark problem by updating the 3D to 2D projection configuration, and generate the new landmark position and 2D projection images with new configuration for 16 patients.
- Solve the wrong position landmark by updating the landmark position in 3D space, and generate the new 2D projection images for 3 patients.
- Confirmation the correctness of all 16 landmarks of all patients.





Female1

Female8

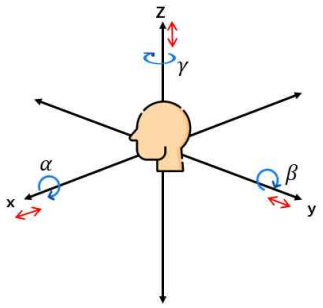


Male5

2022.10.03 - 2022.10.07

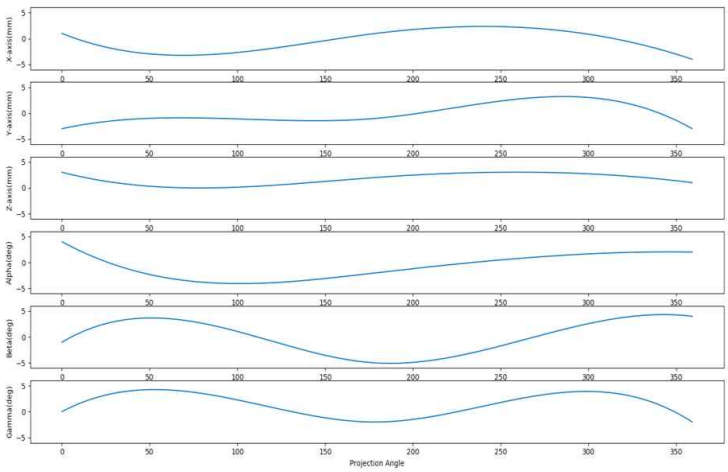
- Generated 3D and 2D head phatom CT images that having the motion during the capturing the images.
- Confirm the correctness on the landmark of the image with motion.

Head Dataset with motion Generation



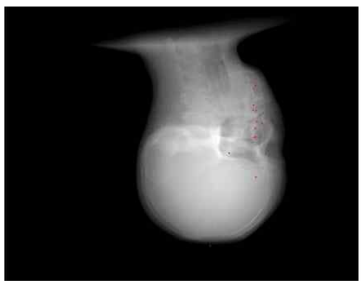
- **Human Motion Limitation:**
  - 10 mm for translation
  - 10° for rotation

- **Human Motion Profile:**



Female3

Female14



Male4

2022.10.10 - 2022.10.14

- Study deep learning landmark detection model and testing the model on 2D projection images of the head phantom with and without motion.

- The landmark detection deep learning result on 2D projection of head phantom without motion.

Pixel space = 1mm				Our Head Dataset					
Model	Backbone	Head	Loss	MRE	MRE_std	SDR			
						2 mm	2.5 mm	3 mm	4 mm
Hourglass	Hourglass	Multistagehead_no deconv	MSE Loss	5.7386	7.191	18.927	27.562	36.59	52.716
HRNet	HRNet_w32	SimpleHead, 0 deconv	MSE Loss	**5.2958**	**7.4726**	**26.318**	**36.256**	**45.606**	**60.341**
	HRNet_w48	SimpleHead, 0 deconv	MSE Loss	5.4312	6.8733	22.051	31.244	40.617	56.464
HRnet v2	HRNet_w18	SimpleHead, 0 deconv	MSE Loss	5.3461	6.8278	22.834	32.222	41.792	57.517
	HRNet_w32	SimpleHead, 0 deconv	MSE Loss	6.1587	6.7034	12.34	18.113	25.272	41.152
HRFormer	HRFormer_base	SimpleHead, 0 deconv	MSE Loss	5.4656	7.0283	22.064	31.298	40.424	56.63
	UNet	SimpleHead, 0 deconv	MSE Loss	6.6458	14.388	24.844	33.638	42.7681	57.23
Simple Baselines	ResNet50	SimpleHead, 3 deconv	MSE Loss	5.831	7.052	18.426	26.25	34.437	49.655
	ResNet101	SimpleHead, 3 deconv	MSE Loss	5.9178	7.2658	19.664	27.807	36.076	50.569
	ResNeXt101	SimpleHead, 3 deconv	MSE Loss	5.8185	6.9302	18.9	27.116	35.367	50.569
	ShuffleNetv2	SimpleHead, 3 deconv	MSE Loss	6.146	7.1206	16.273	23.841	31.833	46.474
	VGG16	SimpleHead, 3 deconv	MSE Loss	5.5648	6.8566	20.137	28.704	37.4788	53.0961
	VGG19	SimpleHead, 3 deconv	MSE Loss	5.9852	7.0054	16.705	24.626	33.038	48.819
	PVT-t	SimpleHead, 3 deconv	MSE Loss	5.851	7.0049	17.888	25.6076	33.6747	48.7712
	PoolFormer	SimpleHead, 3 deconv	MSE Loss	8.8701	11.2503	10.204	15.179	20.716	32.027
	Conformer	SimpleHead, 0 deconv	MSE Loss	6.9051	9.9957	15.1157	22.137	29.313	43.206
	Proposed Backbone	SimpleHead, 3 deconv	MSE Loss	5.61521	6.99756	21.206	30.052	38.565	53.906

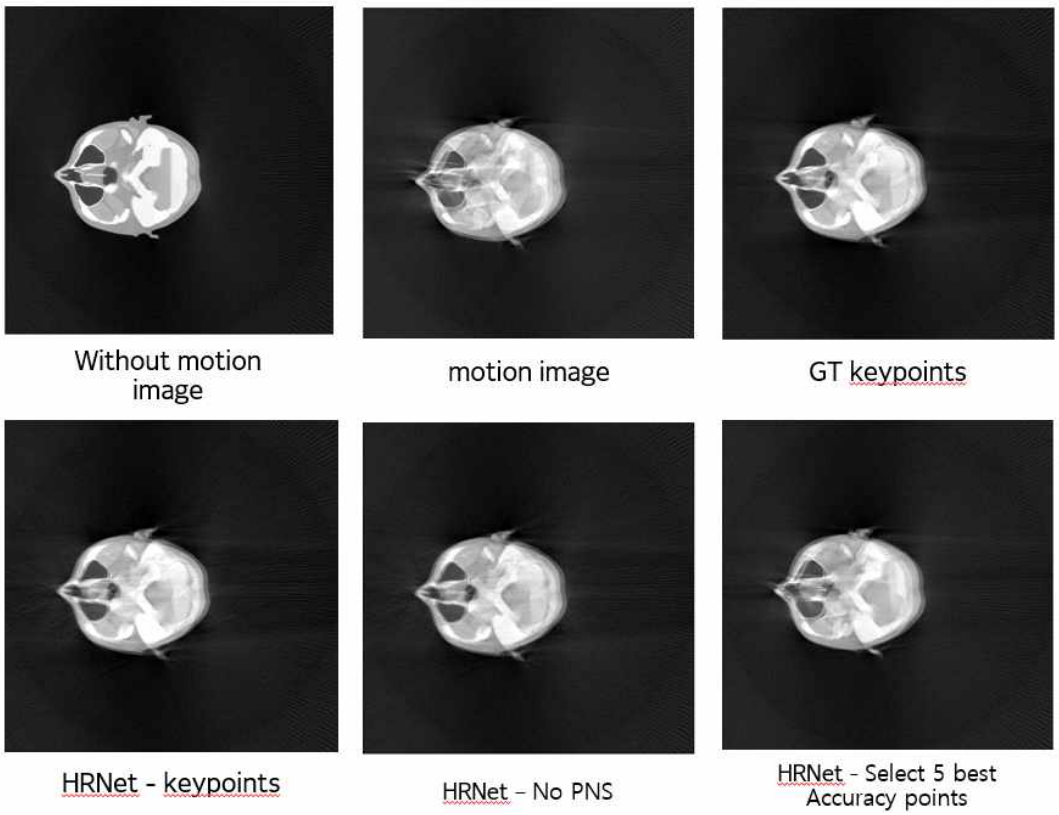
- The landmark detection deep learning result on 2D projection of head phantom with motion.

Pixel space = 1mm				Our Head Dataset					
Model	Backbone	Head	Loss	MRE	MRE_std	SDR			
						2 mm	2.5 mm	3 mm	4 mm
Hourglass	Hourglass	Multistagehead_no deconv	MSE Loss	6.27348	7.42207	17.556	25.251	32.934	47.166
HRNet	HRNet_w32	SimpleHead, 0 deconv	MSE Loss	5.5032	7.1926	22.159	31.348	40.284	55.758
	HRNet_w48	SimpleHead, 0 deconv	MSE Loss	5.5228	7.16864	21.655	30.671	39.688	55.079
HRnet v2	HRNet_w18	SimpleHead, 0 deconv	MSE Loss	5.5377	6.9972	21.487	30.488	39.2708	54.619
	HRNet_w32	SimpleHead, 0 deconv	MSE Loss	6.40972	6.7658	10.611	16.451	23.885	39.724
HRFormer	HRFormer_base	SimpleHead, 0 deconv	MSE Loss	5.77992	7.06001	20.627	29.23	37.741	52.271
	UNet	SimpleHead, 0 deconv	MSE Loss	7.2345	16.6094	24.649	33.302	41.252	54.834
Simple Baselines	ResNet50	SimpleHead, 3 deconv	MSE Loss	6.07026	7.10619	16.985	24.437	32.249	46.435
	ResNet101	SimpleHead, 3 deconv	MSE Loss	5.88554	6.95005	18.499	26.433	34.369	49.72
	ResNeXt101	SimpleHead, 3 deconv	MSE Loss	5.75776	6.88327	18.866	27.037	34.967	49.975
	ShuffleNetv2	SimpleHead, 3 deconv	MSE Loss	6.45642	7.03618	14.182	20.584	27.35	40.309
	VGG16	SimpleHead, 3 deconv	MSE Loss	5.857183	6.98984	17.739	25.731	33.725	48.846
	VGG19	SimpleHead, 3 deconv	MSE Loss	6.230111	7.036603	15.741	23.221	30.586	44.763
	PVT-t	SimpleHead, 3 deconv	MSE Loss	5.94703	6.89899	17.33	24.902	32.537	47.234
	PoolFormer	SimpleHead, 3 deconv	MSE Loss	9.41362	12.11182	9.145	13.553	18.328	28.601
	Conformer	SimpleHead, 0 deconv	MSE Loss	7.49029	10.43431	13.688	19.979	26.51	39.159
	Proposed Metho	SimpleHead, 3 deconv	MSE Loss	5.85627	7.13234	19.068	27.174	35.322	50.108

2022.10.17 - 2022.10.26

- Implement the motion compensation on the head phantom CT images with motion by using the predicted landmarks.
- Testing the motion compensation on the images with varies scenarios that using different information of the landmarks comparing with the original CT images with motion.
- The motion compensation results

Pixel space = 1mm						
Detection Method	Detection Backbone	Motion Compensation Method	SSIM	PSNR	RMSE	
motion_image			0.63254	28.46701	9.77606	
GT motion		simple_projection_shifting	0.62484	28.42424	9.79799	all points
HRNet	HRNet w_32	simple_projection_shifting	0.60188	28.07624	10.13928	all points
HRNet	HRNet w_32	simple_projection_shifting	0.60549	28.11445	10.10149	NO_PNS
HRNet	HRNet w_32	simple_projection_shifting	0.66114	28.75221	9.50608	Best 5
HRNet	HRNet w_32	simple_projection_shifting	**0.66266**	**28.72299**	**9.531891**	Best 5 + bregma
HRNet	HRNet w_32	simple_projection_shifting	0.65693	28.71895	9.54638	Best point



위와 같이 해외연수 결과보고서를 제출합니다.

2022 년 11 월 24 일

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※ 유의사항

1) A4 3장 이상으로 상세히 제출바랍니다.