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Transfer Learning-Based Super-Resolution for High-Precision Medical Imaging

Shedale Sakshi Santosh[1], Kardile Sakshi Mahadev[2], Lokhande Prajakta Bharat[3], Asst. Prof. More S. V.

Students, Department of Computer Engineering[1-3]

Asst. Professor, Department of Computer Engineering[4]

Adsul Technical Campus, Chas, Ahilyanagar, Maharashtra, India

Abstract: *High-resolution medicalimages are critical forpreservingintricate anatomical details essential for accurate diagnosis, effective surgical planning, and creating precise digital twins. However, acquiring such images often requires expensive equipment, specialized personnel, considerable time, and significant financial investment. This research addresses these challenges by proposing an AI-driven specialized super-resolution (SR) framework tailored for medical imaging. Our approach leverages transfer learning by fine-tuning high-performing general-domain SR models (BSRGAN, DPSR, HAT, RealESRGAN, and SwinIR) using approximately 190,000 images from KISTI's Digital Korean dataset. On average, the fine-tuned SR models exhibited a 3.28% improvement in PSNR and a 0.6% increase in SSIM compared to their zero-shot counterparts, underscoring the effectiveness of transfer learning in enhancing both image quality and structural fidelity for medical applications.*

Keywords*:* Super-resolution, transfer learning, digital Korean, medical imaging, human digital twin.

I. INTRODUCTION

Rapid advancements in Artificial Intelligence (AI) technolo- gies have significantly impacted various industries, with the medical field being one of the primary beneficiaries. AI applications in healthcare now encompass the rapid analysis of vast and complex medical imaging data to enhance diagnostic accuracy, the interpretation of clinical records, and the development of AI-driven digital platforms that improve patient care. Among these innovations, the concept of the human digital twin stands out as a groundbreaking development. By digitizing the structure, anatomy, and physiological movements of the human body, this technology enables the virtual replication of dynamic elements such as facial expressions, skeletal movements, and muscular function.

• Development of a specialized SR model for medical imaging by fine-tuning the state-of-the-art general- domain SR models on a large-scale medical imaging dataset, significantly improving diagnostic precision and image clarity essential for clinical applications.

• Conducted rigorous qualitative evaluations alongside robust quantitative assessments using Mean Opinion Scores (MOS), from experienced medical experts.

• The results of the proposed evaluation pipeline ensure the model's clinical relevance, reliability, and applica- bility for creating accurate human digital twins.

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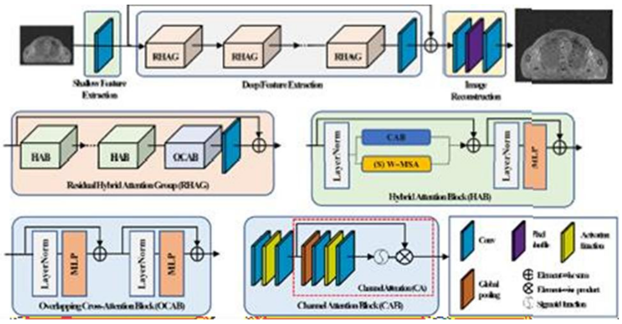

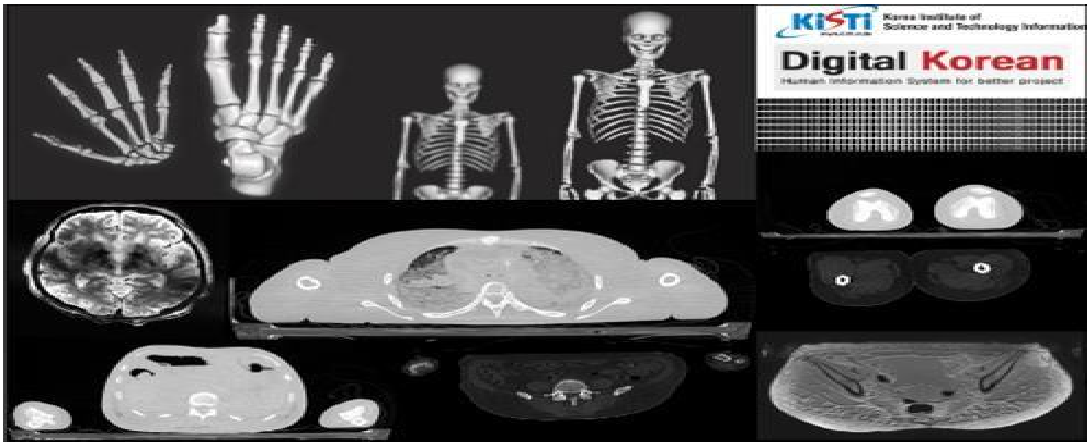

Description	Subjects	Format	Images per Subject	Total Images	Image Size
Full body CT scans of Korean cadavers	Male: 51, Female: 55	DICOM	1,700	180,200	512x512
Full body CT scans of living Korean individuals	Male: 3, Female: 3	DICOM	1,700	10,200	512x512
Micro CT scans of Korean hands, feet, and teeth	Male: 1, Female: 1	DICOM	19,760	39,520	512x512

Table 1.Summary of digital Korean dataset.

Model	Train time (1 step)	Inf. time (128→512)	Inf. time (512→2048)	# Param.
DPSR	0.054s	0.028s	0.381s	3.49M
RealESRGAN	1.870s	0.068s	1.340s	16.70M
BSRGAN	0.524s	0.049s	1.020s	16.70M
SwinIR	1.170s	0.250s	5.840s	35.30M
HAT	2.200s	0.467s	10.90s	41.10M

Table 2. Performance metrics for different base SR models. (Inf. time: Inference Time, # Param.: Number of parameters, s: Seconds, and M: Millions).

	BSRGAN, RealESRGAN, DPSR, SwinIR, and HAT
OS & Environment	Ubuntu 18.04, PyTorch 1.13.1, and CUDA 11.7
GPU Cluster	NVIDIA A100 x 8ea FINE TUNED IMPROVEMENT RATE(%)
Target Scale of Training	Avg. PSNR Avg. SSIM Avg. PSNR Avg. SSIM Upscale by 4 (×4)
Data Shuffle during Training	TRUE
Train Set	HR: 187,266 Images (512×512), LR: 187,266 Images (128×128)
Quantitative Evaluation Set	HR: 5,794 Images (512×512), LR: 5,794 Images (128×128)
Qualitative Evaluation set	HR: 2 set of 50 Images ((1) 512×512, (2) 2,048x2,048), LR: 2 set of 50 Images ((1) 128×128, (2) 512x512)
Optimizer	Adam
Peak Learning Rate	1.00E-06(BSRGAN), 1.00E-04(RealESRGAN), 2.00E-04(DPSR), 1.00E-06(SwinIR), and 1.00E-05(HAT)
Learning Rate Scheduler	Multi Step LR with 0.5 of gamma and {500k, 800k, 900k, 950k, 1,000k} of milestones
Batch Size	24
Total Steps	1,000k

Table 3,Environment and hyperparameters for implementation of the proposed medical image super-resolution models.

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SR MODELS	ZERO-SHOT				PSNR	SSIM
BSRGAN	35.86	0.9226	36.49	0.9269	≈ 1.76	≈ 0.47
RealESRGAN	33.26	0.9085	34.70	0.9146	≈ 4.33	≈ 0.67
DPSR	38.12	0.9356	39.60	0.9421	≈ 3.88	≈ 0.69
SwinIR	36.15	0.9269	37.42	0.9327	≈ 3.51	≈ 0.63
HAT	38.82	0.9410	39.95	0.9461	≈ 2.91	≈ 0.54

Table 4. Summary of quantitative evaluation (PSNR and SSIM).

		Model Rankings									
		BSRGAN_zs	BSRGAN_ft	RealESRGAN_zs	RealESRGAN_ft	DPSR_zs	DPSR_ft	SwinIR_zs	SwinIR_ft	HAT_zs	HAT_ft
1	128→512	7	3	8	4	10	5	9	2	6	1
	512→2,048	9	4	8	3	6	5	10	1	7	2
2	128→512	10	3	7	5	9	4	6	1	8	1
	512→2,048	9	3	8	4	7	5	10	2	6	1
3	128→512	6	5	7	4	9	3	8	1	10	2
	512→2,048	7	5	10	4	8	3	9	2	6	1
4	128→512	8	4	9	5	6	3	7	1	10	2
	512→2,048	6	4	7	5	10	3	7	1	9	2
5	128→512	8	4	9	5	6	3	7	1	10	2
	512→2,048	6	4	7	5	10	3	7	1	9	2
Overall Average	128→512	7.8	3.8	8	4.6	8	3.6	7.4	1.2	8.8	1.6
	512→2,048	7.4	4	8	4.2	8.2	3.8	8.6	1.4	7.4	1.6
Overall Rank	128→512	7	4	8	5	8	3	6	1	10	2
	512→2,048	6	4	8	5	9	3	10	1	6	2

Table 5. Results of Mean of Score (MOS) (zs: Zero-Shot, ft: Fine-Tuned).

II. CONCLUSION

This study demonstrates the transformative potential of specialized SR models in addressing the inherent limitations of general-domain approaches for medical imaging. By fine- tuning general-domain SR models using domain-specific datasets such as Digital Korean, we highlight the effective- ness of this adaptation in producing high-resolution medical images with improved anatomical fidelity. Furthermore, the proposed framework not only enhances diagnostic precision but also facilitates the development of more accurate anatomical human models and digital twins, contributing meaningfully to clinical decision-making and patient out- comes. Overall, this study lays a solid foundation for the development of high-quality medical imaging datasets and underscores the critical role of AI-driven SR technologies in shaping the future of medical diagnostics, surgical planning, and precision healthcare.

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REFERENCES

[1]. J. Y. Lee, D. H. Yang, and K. H. Lee, ''Super-resolution of medical images to build precise human digital twins,'' in Proc. Korean Database Conf. (KDBC), vol. 2023, Nov. 2023, pp. 1–10.
[2]. D. Yang, K. Mai Ngoc, I. Shin, K.-H. Lee, and M. Hwang, ''Ensemble- based Out-of-Distribution detection,'' Electronics, vol. 10, no. 5, p. 567, Feb. 2021.
[3]. L.-N. Kwon, D.-H. Yang, M.-G. Hwang, S.-J. Lim, Y.-K. Kim, J.-G. Kim, K.-H. Cho, H.-W. Chun, and K.-W. Park, ''Automated classification of normal control and early-stage dementia based on activities of daily living (ADL) data acquired from smart home environment,'' Int. J. Environ. Res. Public Health, vol. 18, no. 24, p. 13235, Dec. 2021.

[4]. K.-H. Yu, E. Healey, T.-Y. Leong, I. S. Kohane, and A. K. Manrai, ''Medical artificial intelligence and human values,'' New England J. Med., vol. 390, no. 20, pp. 1895–1904, 2024.

[5]. D. Yang, J. Kim, J. Yoo, W. C. Cha, and H. Paik, ''Identifying the risk of sepsis in patients with cancer using digital health care records: Machine learning–based approach,'' JMIR Med. Informat., vol. 10, no. 6, Jun. 2022, Art. no. e37689.