TABLE VIII
M メモリ要件（GB単位）MVT EC ADおよびSTCデータセットで訓練された異常局所化手法。

model	SPADE (WR50)	VAE (R18)	PaDiM R18-Rd100	PaDiM-WR50-Rd550
MVTec AD	1.4	0.09	0.17	3.8
STC	37.0	-	0.21	5.2

結果から、PaDiMはこれらのより現実的なデータに対して頑健であることが示されています。PaDiMの低メモリ消費量と低計算時間、およびその使いやすさは、視覚的産業制御など、多様な応用分野に適しています。

REFERENCES

[1] P. Bergmann, M. Fauser, D. Sattlegger, and C. Steger, "Mvtec ad–a comprehensive real-world dataset for unsupervised anomaly detection," in *CVPR*, 2019.

[2] P. Bergmann, M. Fauser, D. Sattlegger, and C. Steger, "Uninformed students: Student-teacher anomaly detection with discriminative latent embeddings," in *CVPR*, 2020.

[3] S. Venkataramanan, K.-C. Peng, R. V. Singh, and A. Mahalanobis, "Attention guided anomaly localization in images," in *arXiv, 1911.08616*, 2019.

[4] J. Yi and S. Yoon, "Patch svdd: Patch-level svdd for anomaly detection and segmentation," in *arXiv, 2006.16067*, 2020.

[5] N. Cohen and Y. Hoshen, "Sub-image anomaly detection with deep pyramid correspondences," in *arXiv, 2005.02357*, 2020.

[6] L. Bergman and Y. Hoshen, "Classification-based anomaly detection for general data," in *ICLR*, 2020.

[7] T. Cover and P. Hart, "Nearest neighbor pattern classification," *IEEE Transactions on Information Theory*, vol. 13, no. 1, pp. 21–27, 1967.

[8] W. Liu, D. L. W. Luo, and S. Gao, "Future frame prediction for anomaly detection – a new baseline," in *CVPR*, 2018.

[9] P. Bergmann, S. Löwe, M. Fauser, D. Sattlegger, and C. Steger, "Improving unsupervised defect segmentation by applying structural similarity to autoencoders," in *VISIGRAPP*, 2019.

[10] D. Gong, L. Liu, V. Le, B. Saha, M. R. Mansour, S. Venkatesh, and A. van den Hengel, "Memorizing normality to detect anomaly: Memory-augmented deep autoencoder for unsupervised anomaly detection," in *ICCV*, 2019.

[11] C. Huang, F. Ye, J. Cao, M. Li, Y. Zhang, and C. Lu, "Attribute restoration framework for anomaly detection," in *arXiv, 1911.10676*, 2019.

[12] D. P. Kingma and M. Welling, "Auto-encoding variational bayes," in *ICLR*, 2014.

[13] K. Sato, K. Hama, T. Matsubara, and K. Uehara, "Predictable uncertainty-aware unsupervised deep anomaly segmentation," in *IJCNN*, 2019.

[14] W. Liu, R. Li, M. Zheng, S. Karanam, Z.Wu, B. Bhanu, R. J. R., and O. Camps, "Towards visually explaining variational autoencoders," in *CVPR*, 2020.

[15] M. Sabokrou, M. Khalooei, M. Fathy, and E. Adeli, "Adversarially learned one-class classifier for novelty detection," in *CVPR*, 2018.

[16] S. Pidhorskyi, R. Almohsen, D. A. Adjeroh, and G. Doretto, "Generative probabilistic novelty detection with adversarial autoencoders," in *NIPS*, 2018.

[17] S. Akcay, A. Atapour-Abarghouei, and T. P. Breckon, "Ganomaly: Semi-supervised anomaly detection via adversarial training," *ACCV*, 2018.

[18] D. Abati, A. Porrello, S. Calderara, and R. Cucchiara, "Latent space autoregression for novelty detection," in *CVPR*, 2019.

[19] K. H. Kim, S. Shim, Y. Lim, J. Jeon, J. Choi, B. Kim, and A. S. Yoon, "Rapp: Novelty detection with reconstruction along projection pathway," in *ICLR*, 2020.

[20] S. Akçay, A. Atapour-Abarghouei, and T. P. Breckon, "Skip-ganomaly: Skip connected and adversarially trained encoder-decoder anomaly detection," in *IJCNN*, 2019.

[21] P. Perera, R. Nallapati, and B. Xiang, "OCGAN: one-class novelty detection using gans with constrained latent representations," in *CVPR*, 2019.

[22] L. Ruff, R. Vandermeulen, N. Goernitz, L. Deecke, S. A. Siddiqui, A. Binder, E. Müller, and M. Kloft, "Deep one-class classification," in *ICLM*, 2018.

[23] O. Rippel, P. Mertens, and D. Merhof, "Modeling the distribution of normal data in pre-trained deep features for anomaly detection," in *arXiv, 2005.14140*, 2020.

[24] L. Bergman, N. Cohen, and Y. Hoshen, "Deep nearest neighbor anomaly detection," in *arXiv, 2002.10445*, 2020.

[25] S. R. Napoletano P, Piccoli F, "Anomaly detection in nanofibrous materials by cnn-based self-similarity," in *Sensors.*, vol. 18, no. 1, 2018, p. 209.

[26] K. Lee, K. Lee, H. Lee, and J. Shin, "A simple unified framework for detecting out-of-distribution samples and adversarial attacks," in *NIPS*, 2018.

[27] K. He, X. Zhang, S. Ren, and J. Sun, "Deep residual learning for image recognition," in *ICML*, 2016.

[28] S. Zagoruyko and N. Komodakis, "Wide residual networks," in *BMVC*, 2016.

[29] M. Tan and Q. V. Le, "Efficientnet: Rethinking model scaling for convolutional neural networks," in *ICML*, 2019.

[30] K. Pearson, "On lines and planes of closest fit to systems of points in space," *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science*, vol. 2, no. 11, pp. 559–572, 1901.

[31] P. Mahalanobis, "On the generalized distance in statistics," in *National Institute of Science of India*, 1936.

[32] J. Deng, W. Dong, R. Socher, L.-J. Li, K. Li, and L. Fei-Fei, "ImageNet: A Large-Scale Hierarchical Image Database," in *CVPR*, 2009.

TABLE VIII
MEMORY REQUIREMENT IN GB OF THE ANOMALY LOCALIZATION METHODS TRAINED ON THE MVTEC AD AND THE STC DATASET.

model	SPADE (WR50)	VAE (R18)	PaDiM R18-Rd100	PaDiM-WR50-Rd550
MVTec AD	1.4	0.09	0.17	3.8
STC	37.0	-	0.21	5.2

results show that PaDiM can be robust on these more realistic data. PaDiM low memory and time consumption and its ease of use make it suitable for various applications, such as visual industrial control.

REFERENCES

[1] P. Bergmann, M. Fauser, D. Sattlegger, and C. Steger, "Mvtec ad–a comprehensive real-world dataset for unsupervised anomaly detection," in *CVPR*, 2019.

[2] P. Bergmann, M. Fauser, D. Sattlegger, and C. Steger, "Uninformed students: Student-teacher anomaly detection with discriminative latent embeddings," in *CVPR*, 2020.

[3] S. Venkataramanan, K.-C. Peng, R. V. Singh, and A. Mahalanobis, "Attention guided anomaly localization in images," in *arXiv, 1911.08616*, 2019.

[4] J. Yi and S. Yoon, "Patch svdd: Patch-level svdd for anomaly detection and segmentation," in *arXiv, 2006.16067*, 2020.

[5] N. Cohen and Y. Hoshen, "Sub-image anomaly detection with deep pyramid correspondences," in *arXiv, 2005.02357*, 2020.

[6] L. Bergman and Y. Hoshen, "Classification-based anomaly detection for general data," in *ICLR*, 2020.

[7] T. Cover and P. Hart, "Nearest neighbor pattern classification," *IEEE Transactions on Information Theory*, vol. 13, no. 1, pp. 21–27, 1967.

[8] W. Liu, D. L. W. Luo, and S. Gao, "Future frame prediction for anomaly detection – a new baseline," in *CVPR*, 2018.

[9] P. Bergmann, S. Löwe, M. Fauser, D. Sattlegger, and C. Steger, "Improving unsupervised defect segmentation by applying structural similarity to autoencoders," in *VISIGRAPP*, 2019.

[10] D. Gong, L. Liu, V. Le, B. Saha, M. R. Mansour, S. Venkatesh, and A. van den Hengel, "Memorizing normality to detect anomaly: Memory-augmented deep autoencoder for unsupervised anomaly detection," in *ICCV*, 2019.

[11] C. Huang, F. Ye, J. Cao, M. Li, Y. Zhang, and C. Lu, "Attribute restoration framework for anomaly detection," in *arXiv, 1911.10676*, 2019.

[12] D. P. Kingma and M. Welling, "Auto-encoding variational bayes," in *ICLR*, 2014.

[13] K. Sato, K. Hama, T. Matsubara, and K. Uehara, "Predictable uncertainty-aware unsupervised deep anomaly segmentation," in *IJCNN*, 2019.

[14] W. Liu, R. Li, M. Zheng, S. Karanam, Z.Wu, B. Bhanu, R. J. R., and O. Camps, "Towards visually explaining variational autoencoders," in *CVPR*, 2020.

[15] M. Sabokrou, M. Khalooei, M. Fathy, and E. Adeli, "Adversarially learned one-class classifier for novelty detection," in *CVPR*, 2018.

[16] S. Pidhorskyi, R. Almohsen, D. A. Adjeroh, and G. Doretto, "Generative probabilistic novelty detection with adversarial autoencoders," in *NIPS*, 2018.

[17] S. Akcay, A. Atapour-Abarghouei, and T. P. Breckon, "Ganomaly: Semi-supervised anomaly detection via adversarial training," *ACCV*, 2018.

[18] D. Abati, A. Porrello, S. Calderara, and R. Cucchiara, "Latent space autoregression for novelty detection," in *CVPR*, 2019.

[19] K. H. Kim, S. Shim, Y. Lim, J. Jeon, J. Choi, B. Kim, and A. S. Yoon, "Rapp: Novelty detection with reconstruction along projection pathway," in *ICLR*, 2020.

[20] S. Akçay, A. Atapour-Abarghouei, and T. P. Breckon, "Skip-ganomaly: Skip connected and adversarially trained encoder-decoder anomaly detection," in *IJCNN*, 2019.

[21] P. Perera, R. Nallapati, and B. Xiang, "OCGAN: one-class novelty detection using gans with constrained latent representations," in *CVPR*, 2019.

[22] L. Ruff, R. Vandermeulen, N. Goernitz, L. Deecke, S. A. Siddiqui, A. Binder, E. Müller, and M. Kloft, "Deep one-class classification," in *ICLM*, 2018.

[23] O. Rippel, P. Mertens, and D. Merhof, "Modeling the distribution of normal data in pre-trained deep features for anomaly detection," in *arXiv, 2005.14140*, 2020.

[24] L. Bergman, N. Cohen, and Y. Hoshen, "Deep nearest neighbor anomaly detection," in *arXiv, 2002.10445*, 2020.

[25] S. R. Napoletano P, Piccoli F, "Anomaly detection in nanofibrous materials by cnn-based self-similarity," in *Sensors.*, vol. 18, no. 1, 2018, p. 209.

[26] K. Lee, K. Lee, H. Lee, and J. Shin, "A simple unified framework for detecting out-of-distribution samples and adversarial attacks," in *NIPS*, 2018.

[27] K. He, X. Zhang, S. Ren, and J. Sun, "Deep residual learning for image recognition," in *ICML*, 2016.

[28] S. Zagoruyko and N. Komodakis, "Wide residual networks," in *BMVC*, 2016.

[29] M. Tan and Q. V. Le, "Efficientnet: Rethinking model scaling for convolutional neural networks," in *ICML*, 2019.

[30] K. Pearson, "On lines and planes of closest fit to systems of points in space," *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science*, vol. 2, no. 11, pp. 559–572, 1901.

[31] P. Mahalanobis, "On the generalized distance in statistics," in *National Institute of Science of India*, 1936.

[32] J. Deng, W. Dong, R. Socher, L.-J. Li, K. Li, and L. Fei-Fei, "ImageNet: A Large-Scale Hierarchical Image Database," in *CVPR*, 2009.