BAB VI

KESIMPULAN DAN SARAN

6.1 Kesimpulan

Hasil studi ini menunjukkan keberhasilan optimasi terhadap kinerja model AOI untuk deteksi cacat sambungan solder melaui penambahan kelas deteksi cacat *disturbed soldering* menggunakan segmentasi citra dan ekastraksi ditur tekstur GLCM. Melalui modifikasi model tersebut, diperoleh peningkatan kemampuan deteksi cacat sebesar 25% dari model awal yang dikembangkan oleh Fonseka, dkk. [19]. Model deteksi cacat pada sambungan solder yang diusulkan pada penelitian Fonseka, hanya mampu mendeteksi empat kelas cacat. Pengembangan model deteksi cacat *disturbed soldering*, melalui penerapan segmentasi citra dan ekstraksi fitur tekstur berbasis GLCM, berhasil mencapai akurasi hingga 91.75% dan kepresisian hingga 90.20%. Dengan penambahan kelas cacat tersebut, diperoleh model deteksi yang mampu mendeteksi lima kelas cacat soldering sehingga dapat memberikan hasil deteksi yang memadai untuk digunakan di sekolah vokasi. Dengan optimasi model AOI berbasis *Machine Learning* klasik, komputasi algoritma menjadi ringan dan berhasil diimplementasikan pada komputer CPU (Raspberry PI4 B) dengan waktu komputasi yang lebih cepat 55.8% dibandingkan dengan pengujian cacat sambungan solder manual. Hal ini menunjukkan bahwa model algoritma yang diusulkan, menjadi solusi yang efisien terhadap kebutuhan sekolah vokasi dengan anggaran biaya terbatas.

DAFTAR PUSTAKA

[1] P. Veselý *et al.*, "Solder joint quality evaluation based on heating factor," in *Circuit World*, Emerald Group Holdings Ltd., Feb. 2018, pp. 37–44. doi: 10.1108/CW-10-2017-0059.

[2] V. Udaya Sankar, Gayathri Lakshmi, and Y. Siva Sankar, "A Review of Various Defects in PCB," *Journal of Electronic Testing* , 2022, Accessed: Oct. 13, 2022. [Online]. Available: https://doi.org/10.1007/s10836-022-06026-7

[3] M. Franz, J. Nicolics, H. Wohlrabe, and Institute of Electrical and Electronics Engineers, *"Advances in Electronic System Integration" : conference proceedings ISSE 2014 : 37th International Spring Seminar on Electronics Technology : May, 7-11, 2014, Dresden, Germany*. 2014.

[4] L. Ma, W. Xie, Y. Zhang, and X. Feng, "Extreme learning machine based defect detection for solder joints," *Journal of Internet Technology*, vol. 21, no. 5, pp. 1535–1543, 2020, doi: 10.3966/160792642020092105025.

[5] A. A. R. M. A. Ebayyeh and A. Mousavi, "A Review and Analysis of Automatic Optical Inspection and Quality Monitoring Methods in Electronics Industry," *IEEE Access*, vol. 8. Institute of Electrical and Electronics Engineers Inc., pp. 183192–183271, 2020. doi: 10.1109/ACCESS.2020.3029127.

[6] W. Y. Wu, C. W. Hung, and W. bin Yu, "The development of automated solder bump inspection using machine vision techniques," *International Journal of Advanced Manufacturing Technology*, vol. 69, no. 1–4, pp. 509–523, Oct. 2013, doi: 10.1007/s00170-013-4994-x.

[7] R. T. Chin and C. A. Harlow, "Automated Visual Inspection: A Survey," *IEEE Trans Pattern Anal Mach Intell*, vol. PAMI-4, no. 6, pp. 557–573, 1982, doi: 10.1109/TPAMI.1982.4767309.

[8] S.-H. Huang and Y.-C. Pan, "Automated visual inspection in the semiconductor industry: A survey," *Comput Ind*, vol. 66, pp. 1–10, 2015, doi: https://doi.org/10.1016/j.compind.2014.10.006.

[9] T. Czimmermann *et al.*, "Visual-based defect detection and classification approaches for industrial applications—A SURVEY," *Sensors (Switzerland)*, vol. 20, no. 5. MDPI AG, Mar. 01, 2020. doi: 10.3390/s20051459.

[10] G. Acciani, G. Brunetti, and G. Fornarelli, "Application of neural networks in optical inspection and classification of solder joints in surface mount technology," *IEEE Trans Industr Inform*, vol. 2, no. 3, pp. 200–209, Aug. 2006, doi: 10.1109/TII.2006.877265.

[11] Y. Sari, A. R. Baskara, and R. Wahyuni, "Classification of Chili Leaf Disease Using the Gray Level Co-occurrence Matrix (GLCM) and the Support Vector Machine (SVM) Methods," in *2021 Sixth International Conference on Informatics and Computing (ICIC)*, 2021, pp. 1–4. doi: 10.1109/ICIC54025.2021.9632920.

[12] S. U. Khan, N. Islam, Z. Jan, K. Haseeb, S. I. A. Shah, and M. Hanif, "A machine learning-based approach for the segmentation and classification of malignant cells in breast cytology images using gray level co-occurrence matrix (GLCM) and support vector machine (SVM)," *Neural Comput Appl*, vol. 34, no. 11, pp. 8365–8372, 2022, doi: 10.1007/s00521-021-05697-1.

[13] K. Uchida, G. Sakata, T. Watari, Y. Yamakita, and S. Shirakawa, "Generation of microscopic structure of solder material with desirable characteristics based on

deep learning," *Knowl Based Syst*, vol. 258, p. 110017, 2022, doi: https://doi.org/10.1016/j.knosys.2022.110017.
[14] C. Fonseka and P. Jayasinghe, "Color Model Analysis for Solder Pad Segmentationon Printed Circuit Boards," *International Journal of Scientific and Research Publications*, vol. 6, no. 11, 2016, [Online]. Available: www.ijsrp.org
[15] S. Gao, H. Zhang, and H. Mi, "Solder Joint Defect Detection Based on Image Segmentation and Deep Learning," IEEE International Conference on Signal, Information and Data Processing 2019 :, 2019.
[16] W. Wu and Q. Li, "Machine vision inspection of electrical connectors based on improved yolo v3," *IEEE Access*, vol. 8, pp. 166184–166196, 2020, doi: 10.1109/ACCESS.2020.3022405.
[17] P. Li, X. Lin, J. Jing, and L. Zhang, "Defect Detection in Fabrics Using Local Binary Patterns," 2014.
[18] H. Jaya, S. Haryoko, L. Taris, and P. Ida, "Use of Remote Lab for Online and Real time Practicum At Vocational School in Indonesia," *International Journal of Online and Biomedical Engineering (iJOE)*, vol. 16, no. 05, pp. 4–14, May 2020, doi: 10.3991/ijoe.v16i05.13201.
[19] C. L. S. C. Fonseka and J. A. K. S. Jayasinghe, "Implementation of an Automatic Optical Inspection System for Solder Quality Classification of THT Solder Joints," *IEEE Trans Compon Packaging Manuf Technol*, vol. 9, no. 2, pp. 353–366, Feb. 2019, doi: 10.1109/TCPMT.2018.2864666.
[20] J. Chen and X. Ran, "Deep Learning With Edge Computing: A Review," *Proceedings of the IEEE*, vol. 107, no. 8, pp. 1655–1674, 2019, doi: 10.1109/JPROC.2019.2921977.
[21] R. Huang, J. Gu, X. Sun, Y. Hou, and S. Uddin, "A Rapid Recognition Method for Electronic Components Based on the Improved YOLO-V3 Network," *Electronics (Basel)*, vol. 8, no. 8, 2019, doi: 10.3390/electronics8080825.
[22] F. Timm and E. Barth, "Novelty detection for the inspection of light-emitting diodes," *Expert Syst Appl*, vol. 39, no. 3, pp. 3413–3422, 2012, doi: https://doi.org/10.1016/j.eswa.2011.09.029.
[23] Y. J. Cha, W. Choi, and O. Büyüköztürk, "Deep Learning-Based Crack Damage Detection Using Convolutional Neural Networks," *Computer-Aided Civil and Infrastructure Engineering*, vol. 32, no. 5, pp. 361–378, May 2017, doi: 10.1111/mice.12263.
[24] H. Wu, "Solder joint defect classification based on ensemble learning," *Soldering & Surface Mount Technology,* , vol. Vol. 29, no. Issue: 3, 2017.
[25] K. Zhang and H. Shen, "Solder joint defect detection in the connectors using improved faster-rcnn algorithm," *Applied Sciences (Switzerland)*, vol. 11, no. 2, pp. 1–15, Jan. 2021, doi: 10.3390/app11020576.
[26] J. Li, N. Cai, Z. Mo, G. Zhou, and H. Wang, "IC solder joint inspection via generator-adversarial-network based template," *Mach Vis Appl*, vol. 32, no. 4, Jul. 2021, doi: 10.1007/s00138-021-01218-1.
[27] S. Liao, C. Huang, H. Zhang, J. Gong, M. Li, and Z. Wang, "Object detection of welding defects in SMT electronics production based on deep learning," in *2022 23rd International Conference on Electronic Packaging Technology (ICEPT)*, 2022, pp. 1–5. doi: 10.1109/ICEPT56209.2022.9873297.
[28] M. Saqlain, B. Jargalsaikhan, and J. Y. Lee, "A voting ensemble classifier for wafer

map defect patterns identification in semiconductor manufacturing," *IEEE Transactions on Semiconductor Manufacturing*, vol. 32, no. 2, pp. 171–182, May 2019, doi: 10.1109/TSM.2019.2904306.

[29] J. D. Song, Y. G. Kim, and T. H. Park, "SMT defect classification by feature extraction region optimization and machine learning," *International Journal of Advanced Manufacturing Technology*, vol. 101, no. 5–8, pp. 1303–1313, Apr. 2019, doi: 10.1007/s00170-018-3022-6.

[30] P. S. Mali, "Implementation of Reflow Soldering Oven," *International Journal of Emerging Technologies in Engineering Research (IJETER)*, vol. 4, 2016, doi: 10.13140/RG.2.2.31844.45449.

[31] S. Naveen Venkatesh, B. Rebecca Jeyavadhanam, A. M. Moradi Sizkouhi, S. M. Esmailifar, M. Aghaei, and V. Sugumaran, "Automatic detection of visual faults on photovoltaic modules using deep ensemble learning network," *Energy Reports*, vol. 8, pp. 14382–14395, 2022, doi: https://doi.org/10.1016/j.egyr.2022.10.427.

[32] T. and S. R. S. and P. M. E. and M. K. Anand R. and Shanthi, "GLCM Feature-Based Texture Image Classification Using Support Vector Machine," in *3rd EAI International Conference on Big Data Innovation for Sustainable Cognitive Computing*, A. and M. S. and L. J. Haldorai Anandakumar and Ramu, Ed., Cham: Springer International Publishing, 2022, pp. 143–154.

[33] R. Garner and D. Taylor, "Surface mount packaging," *Microelectronics J*, vol. 17, no. 3, pp. 5–13, 1986, doi: https://doi.org/10.1016/S0026-2692(86)80170-7.

[34] A. Amole, O. Adewuyi, and O. Akinde, "Fabrication of Electronic Circuits Using Through- Hole PCB Technology: An Appraisal," Oct. 2021.

[35] E. N. Malamas, E. G. M. Petrakis, M. Zervakis, L. Petit, and J.-D. Legat, "A survey on industrial vision systems, applications and tools," *Image Vis Comput*, vol. 21, no. 2, pp. 171–188, 2003, doi: https://doi.org/10.1016/S0262-8856(02)00152-X.

[36] G. di Leo, C. Liguori, A. Pietrosanto, and P. Sommella, "A vision system for the online quality monitoring of industrial manufacturing," *Opt Lasers Eng*, vol. 89, pp. 162–168, 2017, doi: https://doi.org/10.1016/j.optlaseng.2016.05.007.

[37] S. Shirmohammadi and A. Ferrero, "Camera as the Instrument: The Rising Trend of Vision Based Measurement," *Instrumentation & Measurement Magazine, IEEE*, vol. 17, pp. 41–47, Oct. 2014, doi: 10.1109/MIM.2014.6825388.

[38] T. A. A. Tosta, P. R. de Faria, L. A. Neves, and M. Z. do Nascimento, "Evaluation of statistical and Haralick texture features for lymphoma histological images classification," *Comput Methods Biomech Biomed Eng Imaging Vis*, vol. 9, no. 6, pp. 613–624, 2021, doi: 10.1080/21681163.2021.1902401.

[39] N. G. Shankar and Z. W. Zhong, "A rule-based computing approach for the segmentation of semiconductor defects," *Microelectronics J*, vol. 37, no. 6, pp. 500–509, 2006, doi: https://doi.org/10.1016/j.mejo.2005.07.018.

[40] D.-H. Kim *et al.*, "Smart Machining Process Using Machine Learning: A Review and Perspective on Machining Industry," *International Journal of Precision Engineering and Manufacturing-Green Technology*, vol. 5, no. 4, pp. 555–568, 2018, doi: 10.1007/s40684-018-0057-y.

[41] S. Fonseka and J. A. K. S. Jayasinghe, "Feature Extraction and Template Matching Algorithms Classification for PCB Fiducial Verification," *Journal of Achievements in Materials and Manufacturing Engineering*, vol. 1, pp. 14–32, Oct. 2018, doi: 10.5604/01.3001.0011.6015.

[42] C. L. S. C. Fonseka and J. A. K. S. Jayasinghe, “Implementation of an Automatic Optical Inspection System for Solder Quality Classification of THT Solder Joints,” *IEEE Trans Compon Packaging Manuf Technol*, vol. 9, no. 2, pp. 353–366, 2019, doi: 10.1109/TCPMT.2018.2864666.

[43] T. J. Singler, X. Zhang, and K. A. Brakke, “Computer Simulation of Solder Bridging Phenomena,” *J Electron Packag*, vol. 118, no. 3, pp. 122–126, Sep. 1996, doi: 10.1115/1.2792141.

[44] H. Mittal, A. C. Pandey, M. Saraswat, S. Kumar, R. Pal, and G. Modwel, “A comprehensive survey of image segmentation: clustering methods, performance parameters, and benchmark datasets,” *Multimed Tools Appl*, vol. 81, no. 24, pp. 35001–35026, 2022, doi: 10.1007/s11042-021-10594-9.

[45] K. K. D. Ramesh, G. Kiran Kumar, K. Swapna, D. Datta, and S. Suman Rajest, “A review of medical image segmentation algorithms,” *EAI Endorsed Trans Pervasive Health Technol*, vol. 7, no. 27, 2021, doi: 10.4108/eai.12-4-2021.169184.

[46] S. and T. X.-C. and Y. J. Li Lingfeng and Luo, “A Variational Convex Hull Algorithm,” in *Scale Space and Variational Methods in Computer Vision*, M. and M. J. Lellmann Jan and Burger, Ed., Cham: Springer International Publishing, 2019, pp. 224–235.

[47] R. L. Graham, “An Efficient Algorithm for Determining the Convex Hull of a Finite Planar Set,” *Inf. Process. Lett.*, vol. 1, pp. 132–133, 1972.

[48] B. Ramesh, H. Yang, G. Orchard, N. A. le Thi, S. Zhang, and C. Xiang, “DART: Distribution Aware Retinal Transform for Event-Based Cameras,” *IEEE Trans Pattern Anal Mach Intell*, vol. 42, no. 11, pp. 2767–2780, 2020, doi: 10.1109/TPAMI.2019.2919301.

[49] A. Rodtook and S. Chucherd, “Optic disc localization using graph traversal algorithm along blood vessel in polar retinal image,” *Bulletin of Electrical Engineering and Informatics*, vol. 11, no. 6, pp. 3301–3312, Dec. 2022, doi: 10.11591/eei.v11i6.3618.

[50] C. G. M. Meskers *et al.*, “Automated recognition of functioning, activity and participation in COVID-19 from electronic patient records by natural language processing: a proof- of- concept,” *Ann Med*, vol. 54, no. 1, pp. 235–243, 2022, doi: 10.1080/07853890.2021.2025418.

[51] S. T. Kandukuri, J. S. L. Senanyaka, V. K. Huynh, and K. G. Robbersmyr, “A Two-Stage Fault Detection and Classification Scheme for Electrical Pitch Drives in Offshore Wind Farms Using Support Vector Machine,” *IEEE Trans Ind Appl*, vol. 55, no. 5, pp. 5109–5118, 2019, doi: 10.1109/TIA.2019.2924866.

[52] E. B. Troccoli, A. G. Cerqueira, J. B. Lemos, and M. Holz, “K-means clustering using principal component analysis to automate label organization in multi-attribute seismic facies analysis,” *J Appl Geophy*, vol. 198, p. 104555, 2022, doi: https://doi.org/10.1016/j.jappgeo.2022.104555.

UNIVERSITAS ATMA JAYA YOGYAKARTA