RANCANG BANGUN SISTEM PEMUTAR TELUR OTOMATIS TERINTEGRASI *OBJECT DETECTION* PADA *EGG INCUBATOR* UNTUK OPTIMALISASI KEBERHASILAN PENETASAN

SKRIPSI

Diajukan untuk memenuhi sebagian syarat untuk memperoleh gelar
Sarjana Teknik di Program Studi Mekatronika dan Kecerdasan Buatan

Oleh:
Galih Multi Lidzikri
2103739

PROGRAM STUDI MEKATRONIKA DAN KECERDASAN BUATAN
KAMPUS UPI DI PURWAKARTA
UNIVERSITAS PENDIDIKAN INDONESIA
2025

LEMBAR HAK CIPTA

RANCANG BANGUN SISTEM PEMUTAR TELUR OTOMATIS TERINTEGRASI *OBJECT DETECTION* PADA *EGG INCUBATOR* UNTUK OPTIMALISASI KEBERHASILAN PENETASAN

Oleh,

Galih Multi Lidzikri

Sebuah skripsi yang diajukan untuk memenuhi salah satu syarat memperoleh gelar Sarjana Teknik pada Program Studi Mekatronika dan Kecerdasan Buatan

LEMBAR PENGESAHAN

Galih Multi Lidzikri

2103739

RANCANG BANGUN SISTEM PEMUTAR TELUR OTOMATIS TERINTEGRASI *OBJECT DETECTION* PADA *EGG INCUBATOR* UNTUK OPTİMALISASI KEBERHASILAN PENETASAN

Disetujui dan disahkan oleh pembimbing,

Pembimbing 1,

Diky Zakaria S.Pd., M.T.

NIP. 920211019931203101

Pembimbing 2,

Muhammad Rizalul Wahid, S.Si., M.T.

NIP. 920210919940401101

Mengetahui,

Ketua Program Studi

Mekatronika dan Kecerdasan Buatan

Dewi Indriati Hadi Putri, S.Pd., M.T.

NIP. 920190219900126201

ABSTRAK

Penetasan telur ayam memerlukan pengaturan suhu, kelembapan, dan pemutaran telur yang tepat untuk mencapai tingkat keberhasilan optimal. Penelitian ini bertujuan merancang dan membangun sistem pemutar telur otomatis berbasis mekanisme rak geser yang terintegrasi dengan kendali suhu PID, kelembapan ON/OFF, serta modul deteksi objek pada *egg incubator*. Metode penelitian menggunakan pendekatan *Research and Development* (RnD) dengan model ADDIE, meliputi analisis kebutuhan, perancangan, pengembangan, implementasi, dan evaluasi. Sistem dikendalikan oleh Arduino Mega dengan antarmuka *dashboard* berbasis Python PyQt5 untuk *monitoring* dan kontrol *real-time*, serta *object detection* menggunakan kamera. Pemutar telur beroperasi setiap satu jam selama 17 hari awal inkubasi. Pengujian dilakukan dengan 10 butir telur ayam, memantau kestabilan suhu (36–38 °C) dan kelembapan (55% RH) melalui sensor NTC 10k dan DHT22. Hasil menunjukkan sistem mampu mempertahankan suhu dengan deviasi ±0,3 °C dan kelembapan ±3% RH. Validasi sensor menghasilkan MAE suhu 0,21 °C dan MAPE 0,58%, sedangkan kelembapan memiliki MAE 1,12% dan MAPE 2,04%, menunjukkan akurasi yang baik. Pemutar telur bekerja stabil sesuai jadwal tanpa gangguan mekanis. Tingkat keberhasilan penetasan mencapai 30%, dengan kegagalan sebagian besar disebabkan kematian embrio. Integrasi *object detection* memudahkan identifikasi kondisi pasca-menetas secara visual. Kesimpulannya, sistem ini efektif menjaga parameter inkubasi dan memudahkan pemantauan, meskipun keberhasilan penetasan dipengaruhi faktor biologis di luar sistem.

Kata kunci: *egg incubator*, pemutar telur otomatis, PID, deteksi objek, ADDIE.

ABSTRACT

Hatching chicken eggs requires precise control of temperature, humidity, and egg turning to achieve optimal hatchability. This study aims to design and develop an automatic egg turning system using a sliding rack mechanism integrated with PID temperature control, ON/OFF humidity control, and an object detection module in an egg incubator. The research employed a Research and Development (RnD) approach with the ADDIE model, consisting of needs analysis, design, development, implementation, and evaluation. The system is controlled by an Arduino Mega with a Python–PyQt5-based dashboard for real-time monitoring and control, and object detection using a camera. The egg turner operates every hour during the first 17 days of incubation. Testing was conducted with 10 chicken eggs, monitoring temperature stability (36–38 °C) and humidity (55% RH) using NTC 10k and DHT22 sensors. Results show that the system maintained temperature with a deviation of ±0.3 °C and humidity within ±3% RH. Sensor validation yielded a temperature MAE of 0.21 °C and MAPE of 0.58%, while humidity showed an MAE of 1.12% and MAPE of 2.04%, indicating good accuracy. The egg turner operated reliably according to schedule without mechanical failures. The hatching success rate reached 30%, with most failures caused by embryo mortality. The integration of object detection facilitated visual identification of post-hatch conditions. In conclusion, the system effectively maintained incubation parameters and simplified monitoring, although hatchability was influenced by biological factors beyond the system's control.

Keywords*: egg incubator, automatic egg turner, PID, object detection, ADDIE.*

DAFTAR ISI

DAFAR GAMBAR

DAFTAR TABEL

DAFTAR PUSTAKA

[1] M. Artiyasa, Waryani, D. Muhammad Taufik, and A. De Wibowo, "Sistem Penetasan Telur Berbasis Plc," *J. Rekayasa Teknol. Nusa Putra*, vol. 7, no. 1, pp. 45–53, 2021, doi: 10.52005/rekayasa.v7i1.64.

[2] B. Setiawan, "Hybrid Solar Heat Accumulator Control for Egg Hatcher Applying Power Hysteresis Method," in *International Conference on Electrical and Information Technology (IEIT)*, 2022, pp. 231–237.

[3] L. Niranjan, C. Venkatesan, A. R. Suhas, S. Satheeskumaran, and S. A. Nawaz, "Design and implementation of chicken egg incubator for hatching using IoT," *Int. J. Comput. Sci. Eng.*, vol. 24, no. 4, pp. 363–372, 2021, doi: 10.1504/IJCSE.2021.117018.

[4] P. Dutta and N. Anjum, "Optimization of Temperature and Relative Humidity in an Automatic Egg Incubator Using Mamdani Fuzzy Inference System," *Int. Conf. Robot. Electr. Signal Process. Tech.*, pp. 12–16, 2021, doi: 10.1109/ICREST51555.2021.9331155.

[5] Sukandar, Sunardi, M. Khalwatu, M. A. Rahman, and Z. Abidin, "Design of automatic eggs hatchery as preservation of turtle in coastal of East Java," *E3S Web Conf.*, vol. 153, pp. 1–4, 2020, doi: 10.1051/e3sconf/202015301002.

[6] P. Tiam Kapen, M. Youssoufa, M. Foutse, H. Manfouo, and F. O. Njotchui Mbakop, "Design and prototyping of a low-cost, energy efficient eggs incubator in developing countries: A case study of Cameroon," *Sci. African*, vol. 10, 2020, doi: 10.1016/j.sciaf.2020.e00618.

[7] J. Gutiérrez, S., Contreras, G., Ponce, H., Cardona, M., Amadi, H., & Enríquez-Zarate, "Development of hen eggs smart incubator for hatching system based on internet of things," *IEEE 39th Cent. Am. Panama Conv. (CONCAPAN XXXIX)*, vol. 20190, pp. 1–5, 2019.

[8] S. Shafiudin and N. Kholis, "Monitoring System and Temperature Controlling on PID Based Poultry Hatching Incubator," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 336, no. 1, 2018, doi: 10.1088/1757-

899X/336/1/012007.

[9] A. A. Aldair, A. T. Rashid, and M. Mokayef, “Design and Implementation of Intelligent Control System for Egg Incubator Based on IoT Technology,” *2018 4th Int. Conf. Electr. Electron. Syst. Eng. ICEESE 2018*, pp. 49–54, 2018, doi: 10.1109/ICEESE.2018.8703539.

[10] F. Peprah, S. Gyamfi, M. Amo-Boateng, E. Buadi, and M. Obeng, “Design and construction of smart solar powered egg incubator based on GSM/IoT,” *Sci. African*, vol. 17, 2022, doi: 10.1016/j.sciaf.2022.e01326.

[11] G. da S. Oliveira, V. M. dos Santos, J. C. Rodrigues, and S. T. Nascimento, “Effects of different egg turning frequencies on incubation efficiency parameters,” *Poult. Sci.*, vol. 99, no. 9, pp. 4417–4420, 2020, doi: 10.1016/j.psj.2020.05.045.

[12] S. Mohlalisi, T. Koetje, and T. Thamae, “Design and development of an artificial incubator,” *Smart Agric. Technol.*, vol. 7, no. October 2023, p. 100387, 2024, doi: 10.1016/j.atech.2023.100387.

[13] D. Zakaria;, A. G. Abdullah;, A. Alrasyid;, M. H. Muttaqin;, M. S. Gianti;, and A. Ramelan, “Temperature Control System in Egg Incubator Based on PID with Graphical User Interface,” in *IEEE International Conference on Smart Mechatronics (ICSMech)*, 2024.

[14] M. F. Omar, H. C. M. Haris, M. N. Hidayat, I. Ismail, and M. N. Seroji, “Smart eggs incubator system,” *Int. J. Simul. Syst. Sci. Technol.*, vol. 17, no. 41, pp. 35.1-35.7, 2016, doi: 10.5013/IJSSST.a.17.41.35.

[15] B. B. Guo *et al.*, “Improvement of goose embryonic and muscular developments by wider angle egg turning during incubation and the regulatory mechanisms,” *Poult. Sci.*, vol. 100, no. 12, p. 101477, 2021, doi: 10.1016/j.psj.2021.101477.

[16] I. M. Alim *et al.*, “Histologi Perkembangan Embrio Telur Ayam Kampung pada Masa Inkubasi dari Hari ke nol sampai hari ke tujuh,” *J. Ilm. Mhs. Sains Unisma Malang*, vol. 1, no. 1, p. 28, 2023, doi: 10.33474/jimsum.v1i1.20085.

[17] Sugiarto, “Rancang Bangun Inkubator Tetas Telur Otomatis di Peternakan

Unggas Dengan Metode Proportional Integral Derivative," *JEKIN - J. Tek. Inform.*, vol. 1, no. 1, pp. 18–28, 2021, doi: 10.58794/jekin.v1i1.21.

[18] N. P. Sermalia, M. Arifin, and M. Sihite, "Pengaruh Letak Telur pada Mesin Tetas terhadap Persentase Susut Bobot Telur, Daya Tetas dan Bobot Tetas DOC (Day Old Chick)," *Pros. Semin. Nas. Pembang. dan Pendidik. Vokasi Pertan.*, vol. 2, no. 1, pp. 151–164, 2021.

[19] Jhulinda Nizar Wati, Meta Yantidewi, and Utama Alan Deta, "Pengaruh Jumlah Lampu Pijar terhadap Suhu Mesin Penetas Telur Berbasis Raspberry Pi," *J. Kolaboratif Sains*, vol. 6, no. 7, pp. 575–585, 2023, doi: 10.56338/jks.v6i7.3784.

[20] A. Agusdika and D. Purwanti, "Implementasi Sensor Suhu dan Kelembaban sebagai Inkubator Penetas Telur Ayam Lokal Berbasis Web Server," *Ina. Indones. J. Electr. Eletronics Eng.*, vol. 2, no. 2, pp. 43–47, 2019, doi: 10.26740/inajeee.v2n2.p9-13.

[21] F. R. Hasibuan, S. Amelia, Y. Sinurat, P. R. Achyari, and F. E. Saragih, "Perbandingan Pertumbuhan Embrio Ayam Kampung Dengan Variasi Metode Pengeraman," *J. Biol.*, vol. 1, no. 1, pp. 1–10, 2023, doi: 10.47134/biology.v1i1.1929.

[22] N. Iksan, L. Hidayati, T. Andrasto, and K. Fathoni, "Sistem Kendali Suhu dan Kelembapan pada Alat Penetas Telur Berbasis Fuzzy Logic Controller," *J. Edukasi dan Penelit. Inform.*, vol. 8, no. 2, p. 245, 2022, doi: 10.26418/jp.v8i2.53246.

[23] H. Subagja, Z. A. Nadia, and N. Ningsih, "The Egg-Turning Technique on The Hatching Performance of Hybrid Duck Eggs," *Int. J. Technol. Food Agric.*, vol. 1, no. 1, pp. 43–47, 2024, doi: 10.25047/tefa.v1i1.4540.

[24] F. Chen *et al.*, "Improving duckling hatchability and quality by optimization of egg turning angle during incubation," *Poult. Sci.*, vol. 103, no. 10, pp. 1–7, 2024, doi: 10.1016/j.psj.2024.103937.

[25] P. González-Redondo and A. R. Martínez-Domínguez, "Comparison of several turning frequencies during the storage period of red-legged partridge (Alectoris rufa) hatching eggs," *Rev. Bras. Cienc. Avic. / Brazilian J. Poult.*

Sci., vol. 21, no. 3, 2019, doi: 10.1590/1806-9061-2018-0882.

[26] M. B. Ramli, H. P. Lim, M. S. Wahab, and M. F. M. Zin, "Egg Hatching Incubator Using Conveyor Rotation System," *Procedia Manuf.*, vol. 2, no. February, pp. 527–531, 2015, doi: 10.1016/j.promfg.2015.07.091.

[27] M. J. A. Soeb, M. R. Al Mamun, S. Shammi, M. Uddin, and R. A. Eimon, "Design and Fabrication of Low-Cost Incubator to Evaluate Hatching Performance of Egg," *Eur. J. Eng. Technol. Res.*, vol. 6, no. 7, pp. 91–96, 2021, doi: 10.24018/ejeng.2021.6.7.2662.

[28] H. Haris, N. Effiandi, S. Afriyani, and F. Saputra, "Perancangan Mesin Penetas Telur Unggas Otomatis Menggunakan Acci (Automatic Computer Control Incubator) Kapasitas 360 Butir," *J. Tek. Mesin*, vol. 16, no. 2, pp. 182–188, 2023, doi: 10.30630/jtm.16.2.1242.

[29] G. Setyawan, T. P. Satya, M. R. Al Fauzan, F. Puspasari, I. Fahrurrozi, and E. M. D. Admoko, "Penentuan Jarak Baca Terbaik Pada Sistem Pemindai Berbasis Larik Sensor Ultrasonik," *J. Ilmu Fis. | Univ. Andalas*, vol. 12, no. 1, pp. 44–52, 2020, doi: 10.25077/jif.12.1.44-52.2020.

[30] Khalilurrakhman and Thamrin, "Penggunaan Mikrokontroller Arduino Mega 2560 pada Sistem Closed House Ayam Broiler," *Voteteknika (Vocational Tek. Elektron. dan Inform.*, vol. 8, no. 1, p. 116, 2020, doi: 10.24036/voteteknika.v8i1.107765.

[31] S. J. Yun, Y. K. Yun, and Y. S. Kim, "A low flicker TRIAC dimmable direct AC LED driver for always-on LED arrays," *IEEE Access*, vol. 8, pp. 198925–198934, 2020, doi: 10.1109/ACCESS.2020.3034334.

[32] M. K. Metwaly, H. Z. Azazi, S. A. Deraz, M. E. Dessouki, and M. S. Zaky, "Power Factor Correction of Three-Phase PWM AC Chopper Fed Induction Motor Drive System Using HBCC Technique," *IEEE Access*, vol. 7, pp. 43438–43452, 2019, doi: 10.1109/ACCESS.2019.2907791.

[33] Taufik, W. Xiong, J. Sato, and Saidah, "Ambient light adaptive LED light dimmer," *Telkomnika (Telecommunication Comput. Electron. Control.*, vol. 17, no. 1, pp. 438–447, 2019, doi: 10.12928/TELKOMNIKA.v17i1.10114.

[34] A. Junaidi and C. Kartiko, "Design of Pond Water Quality Monitoring

System Based on Internet of Things and Pond Fish Market in Real-Time to Support the Industrial Revolution 4.0," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 771, no. 1, pp. 0–6, 2020, doi: 10.1088/1757-899X/771/1/012034.

[35] A. H. M. Nasution, S. Indriani, N. Fadhilah, C. Arifin, and S. P. Tamba, "Pengontrolan Lampu Jarak Jauh Dengan Nodemcu Menggunakan Blynk," *J. TEKINKOM*, vol. 2, pp. 93–98, 2019.

[36] R. Agustian, A. Bintoro, R. Rosdiana, M. Jannah, S. Salahuddin, and W. K. A. Al-Ani, "Design of Automatic Coffee Bean Roaster Based on Arduino Uno Microcontroller," *Int. J. Adv. Data Inf. Syst.*, vol. 3, no. 2, pp. 49–57, 2022, doi: 10.25008/ijadis.v3i2.1238.

[37] Z. Oktarina and H. Habibullah, "Rancang Bangun Coffee Mix Berbasis Mikrokontroller," *JTEIN J. Tek. Elektro Indones.*, vol. 4, no. 2, pp. 715–723, 2023, doi: 10.24036/jtein.v4i2.489.

[38] R. Regidor, R. J. Lasaga, M. C. Suansing, and P. Taculod, "Development of Automatic Object Lifter," *J. Emerg. Technol. Innov.*, vol. 1, no. 1, pp. 20–26, 2023, doi: 10.55990/umjeti.v1i1.02.

[39] Y. S. Dwanoko and F. F. S. Arin, "Implementation of User Centered Design methodology for designing information systems introduction to culture based on mobile applications," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 1098, no. 6, p. 062004, 2021, doi: 10.1088/1757-899x/1098/6/062004.

[40] F. Hendajani, A. Mughni, I. P. Wardhani, and A. Hakim, "Modeling Automatic Room Temperature and Humidity Monitoring System with Fan Control on the Internet of Things," *ComTech Comput. Math. Eng. Appl.*, vol. 13, no. 2, pp. 75–85, 2022, doi: 10.21512/comtech.v13i2.7433.

[41] F. Puspasari, T. P. Satya, U. Y. Oktiawati, I. Fahrurrozi, and H. Prisyanti, "Analisis Akurasi Sistem sensor DHT22 berbasis Arduino terhadap Thermohygrometer Standar," *J. Fis. dan Apl.*, vol. 16, no. 1, p. 40, 2020, doi: 10.12962/j24604682.v16i1.5776.

[42] I. Heryanto, S. Arum, and M. Noor, "Sistem Otomasi Suhu dan Kelembaban Pada Greenhouse Berbasis Sensor DHT22 dan Mikrokontroler," *J. Sist. Kelistrikan*, vol. 12, no. 2, 2025.

[43] I. K. Wardani *et al.*, "The feasibility study: Accuracy and precision of DHT 22 in measuring the temperature and humidity in the greenhouse," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 1230, no. 1, 2023, doi: 10.1088/1755-1315/1230/1/012146.

[44] A. H. Sulasmoro, Y. Febrian Sabanise, and M. T. Prihandoyo, "Analisis Kinerja Sensor Dht22 Dan Sensor Lm35 Pada Suhu," *MUST J. Math. Educ.*, vol. 9, no. 2, pp. 45–53, 2024, [Online]. Available: http://doi.org/10.30651/must.v5i1.23646

[45] M. `Toby S. Pratika, I. N. Piarsa, and A. A. K. A. C. Wiranatha, "Rancang Bangun Wireless Relay dengan Monitoring Daya Listrik Berbasis Internet of Things," *JITTER J. Ilm. Teknol. dan Komput.*, vol. 2, no. 3, p. 515, 2021, doi: 10.24843/jtrti.2021.v02.i03.p10.

[46] F. Gumilang, L. Lenni, and A. Kurniawan, "Purwarupa Monitoring Menggunakan Telegram Dan Kontrol Suhu Inkubator Menggunakan Dht-11 Berbasis Arduino," *J. Tek. Elektro*, vol. 7, no. 1, p. 1, 2023, doi: 10.31000/jte.v7i1.9785.

[47] K. George, J., Vikraman, H. K., Sivalingam, Y., Varadharaj, E. K., & Mangalampalli SRN, "Ultrafast Self-Powered Ti–Zn–N Photodetector-Based Optocoupler for Power Electronics Applications," *Energy Technol.*, vol. 12, no. 7, 2024.

[48] O. Y. Hutajulu, M. D. Mendoza, E. Astrid, and R. Rahmadani, "Utilizing Internet of Things Technology in the Development of AC Electrical Circuit Trainer Module," in *ICIESC*, 2024. doi: 10.4108/eai.24-10-2023.2342338.

[49] H. Alrikabi, A. H. Alaidi, and K. Nasser, "The Application of Wireless Communication in IOT for Saving Electrical Energy," *nternational J. Interact. Mob. Technol.*, vol. 14, no. 1, pp. 152–160, 2020.

[50] Z. Azhar, A. R. F. Gani, A. R. F. Gani, and Z. M. Nata, "Inkubator Mesin Tetas Telur Otomatis Berbasis Mikrokontroler Arduino," *STRING (Satuan Tulisan Ris. dan Inov. Teknol.*, vol. 8, no. 2, p. 156, 2023, doi: 10.30998/string.v8i2.16609.

[51] Z. Anthony, E. Erhaneli, Y. Warmi, Z. Zulkarnaini, and A. Anugrah, "A new

windings design for improving single-phase induction motor performance," *Int. J. Electr. Comput. Engginer*, vol. 12, no. 6, pp. 5789–5798, 2022, doi: 10.11591/ijece.v12i6.pp5789-5798.

[52] Z. Zhang, S. Jin, G. Liu, Z. Hou, and J. Zheng, "Model-free adaptive direct torque control for the speed regulation of asynchronous motors," *Processes*, vol. 8, no. 3, pp. 1–10, 2020, doi: 10.3390/pr8030333.

[53] Z. Chen, R. Lin, H. Wang, B. Shi, and Q. Chen, "The effect of incubator humidity on morbidity and mortality in preterm infants: a systematic review," *BMC Pediatr.*, vol. 25, no. 1, pp. 1–12, 2025, doi: 10.1186/s12887-025-05538-3.

[54] I. L. Kharisma, Kamdan, A. R. Firdaus, R. H. Prayoga, F. R. Yasin, and M. A. Tresna Ati, "Construction Of Railway Door Automation Prototypes Using Arduino, Servo Motors and Ultrasonic Sensors," *Digit. Zo. J. Teknol. Inf. dan Komun.*, vol. 14, no. 1, pp. 1–12, 2023, doi: 10.31849/digitalzone.v14i1.13584.

[55] Y. Sumaryana, A. Kusmayadi, R. S. Sundari, D. Y. Heryadi, and I. Nurcahya, "Application of Appropriate Technology for Automatic Hatching Machines in the Kelompok Ternak Bebek Mukti in Rajamandala Village," *Unram J. Community Serv.*, vol. 5, no. 4, pp. 278–282, 2024, doi: 10.29303/ujcs.v5i4.747.

[56] G. Garno, S. Suparno, A. Jamaludin, A. Voutama, and J. Indra, "Implementasi Teknologi Alat Penetas dan Teropong Otomatis Untuk Meningkatkan Daya Tetas Telur Bebek di UKM Beki Karawang," *J. Kreat. Pengabdi. Kpd. Masy.*, vol. 5, no. 10, pp. 3504–3513, 2022, doi: 10.33024/jkpm.v5i10.7174.

[57] G. Youcif Izadeen and I. Sarhan Hussein Kocher, "Smart Egg Incubator Based on Microcontroller: a Review," *Acad. J. Nawroz Univ.*, vol. 11, no. 4, pp. 139–146, 2022, doi: 10.25007/ajnu.v11n4a1401.

[58] S. Shafiudin and N. Kholis, "Sistem Monitoring Dan Pengontrolan Temperatur Pada Inkubator Penetas Telur Berbasis Pid," *J. Mhs. Univ. Negeri Surabaya*, vol. 6, no. 3, pp. 175–184, 2017.

[59] W. R. Azizah and A. W. Wijayanto, “Design and Implementation of an Interactive Dashboard in the Monitoring Process of Flood Vulnerability Index,” in *International Conference on Data Science and Official Statistics*, 2023, pp. 218–232.

[60] P. Chen, “Visualization of real-time monitoring datagraphic of urban environmental quality,” *J. Image Video Process. Res.*, vol. 6, p. 42, 2019.

[61] M. S. Murthy, R. P. R. Kumar, B. Saikiran, and I. Nagaraj, “Real Time Weather Monitoring System using IoT,” in *E3S Web of Conferences*, 2023, pp. 1–10.

[62] H. Zhang and R. S. Cloutier, “Review on One-Stage Object Detection Based on Deep Learning,” *EAI Endorsed Trans. e-Learning*, vol. 7, no. 23, p. 174181, 2022, doi: 10.4108/eai.9-6-2022.174181.

[63] X. Yang, R. B. Bist, S. Subedi, and L. Chai, “A Computer Vision-Based Automatic System for Egg Grading and Defect Detection,” *Animals*, vol. 13, no. 14, 2023, doi: 10.3390/ani13142354.

[64] Diwakar and D. Raj, “Recent Object Detection Techniques: A Survey,” *Int. J. Image, Graph. Signal Process.*, vol. 14, no. 2, pp. 47–60, 2022, doi: 10.5815/ijigsp.2022.02.05.

[65] J. Meng, S. Shen, J. Wang, and C. Zhou, “Object Detection Algorithms Based on Deep Learning: A Review,” *Asian J. Res. Comput. Sci.*, vol. 17, no. 8, pp. 1–12, 2024, doi: 10.9734/ajrcos/2024/v17i7485.

[66] A. M. Nur, Hariman Bahtiar, and Mila Agustiarini Jannah, “Implementasi Algoritma K-Means Clustering Dalam Mengelompokkan Kepatuhan Wajib Pajak Bumi dan Bangunan Dengan Optimasi Elbow,” *Infotek J. Inform. dan Teknol.*, vol. 8, no. 1, pp. 181–192, 2025, doi: 10.29408/jit.v8i1.28644.

[67] M. Hussain, “YOLOv5, YOLOv8 and YOLOv10: The Go-To Detectors for Real-time Vision,” pp. 1–12, 2024, [Online]. Available: http://arxiv.org/abs/2407.02988

[68] R. A. González Rivero *et al.*, “A Low-Cost Calibration Method for Temperature, Relative Humidity, and Carbon Dioxide Sensors Used in Air Quality Monitoring Systems,” *Atmosphere (Basel).*, vol. 14, no. 2, 2023, doi:

10.3390/atmos14020191.

[69] J. A. Abdinoor *et al.*, “Performance of Low-Cost Air Temperature Sensors and Applied Calibration Techniques—A Systematic Review,” *Atmosphere (Basel).*, vol. 16, no. 7, pp. 1–30, 2025, doi: 10.3390/atmos16070842.

[70] K. S. Ladino, M. P. Sama, and V. L. Stanton, “Development and Calibration of Pressure-Temperature-Humidity (PTH) Probes for Distributed Atmospheric Monitoring Using Unmanned Aircraft Systems,” *Sensors*, vol. 22, no. 9, 2022, doi: 10.3390/s22093261.

[71] C. C. Wang, Z. Y. Hou, and J. C. You, “A high-precision CMOS temperature sensor with thermistor linear calibration in the (−5°C, 120°C) temperature range,” *Sensors (Switzerland)*, vol. 18, no. 7, pp. 1–12, 2018, doi: 10.3390/s18072165.

[72] M. N. R. Pratama, H. Fitriyah, and R. R. M. Putri, “Sistem Kendali Suhu dan Kelembapan Udara Tanaman Microgreen Kubis Menggunakan Metode Regresi Linear Berbasis Arduino,” *J. Pengemb. Teknol. Inf. dan Ilmu Komput.*, vol. 7, no. 7, pp. 3478–3486, 2023, [Online]. Available: http://j-ptiik.ub.ac.id

[73] B. Fasel, J. Sporri, J. Chardonnens, J. Kroll, E. Muller, and K. Aminian, “Joint Inertial Sensor Orientation Drift Reduction for Highly Dynamic Movements,” *IEEE J. Biomed. Heal. Informatics*, vol. 22, no. 1, pp. 77–86, 2018, doi: 10.1109/JBHI.2017.2659758.

[74] B. Fatkhurrozi, S. Nisworo, and S. Sumardi, “Optimasi Proses Gasifikasi Menggunakan Logika Fuzzy Mamdani,” *Avitec*, vol. 4, no. 2, p. 151, 2022, doi: 10.28989/avitec.v4i2.1261.

[75] X. Wei *et al.*, “Temperature and relative humidity prediction in South China greenhouse based on machine learning,” *Sci. Rep.*, vol. 15, no. 1, pp. 1–13, 2025, doi: 10.1038/s41598-025-08964-6.

[76] D. Zakaria, A. G. Abdullah, A. Alrasyid, M. H. Muttaqin, M. S. Gianti, and A. Ramelan, “Temperature Control System in Egg Incubator Based on PID with Graphical User Interface,” *ICSMech 2024 - 1st Int. Conf. Smart Mechatronics Transform. Innov. Smart Mechatronics Bridg. AI, Robot. loT*

a Sustain. Futur., pp. 42–47, 2024, doi: 10.1109/ICSMech62936.2024.10812257.

[77] Y. H. Syamsuriana Basri, "Jurnal Ilmiah Wahana Pendidikan," *J. Ilm. Wahana Pendidik. https//jurnal.unibrah.ac.id/index.php/JIWP*, vol. 7, no. 1, pp. 1–7, 2021, doi: 10.5281/zenodo.4662664.

[78] A. R. Kunselman, "A brief overview of pilot studies and their sample size justification," *Fertil. Steril.*, vol. 121, no. 6, pp. 899–901, 2024, doi: 10.1016/j.fertnstert.2024.01.040.

[79] Y. Yanti, A. Rohman, A. Patriana, W. M. Fauzi, A. Mustopa, and R. M. Febrian, "Heat Transfer In Automatic Duck Egg Incubator Using A Light Bulb As The Heater," *SINTEK J. J. Ilm. Tek. Mesin*, vol. 17, no. 2, p. 97, 2023, doi: 10.24853/sintek.17.2.97-101.

[80] V. M. Nakaguchi and T. Ahamed, "Development of an Early Embryo Detection Methodology for Quail Eggs Using a Thermal Micro Camera and the YOLO Deep Learning Algorithm," *Sensors*, vol. 22, no. 15, 2022, doi: 10.3390/s22155820.

[81] A. Jabbar, "The Eggs Turning Frequencies and Turning Angle During Incubation," *Int. J. Anim. Sci. Technol.*, vol. 7, no. 2, pp. 31–34, 2023, doi: 10.11648/j.ijast.20230702.14.

[82] S. Dan, "Comprehensive Energy-Saving Optimization Model of Asynchronous Motor for Voltage Regulation Based on Static Synchronous Compensator," *Energy Eng. J. Assoc. Energy Eng.*, vol. 119, no. 3, pp. 1047–1057, 2022, doi: 10.32604/ee.2022.015594.

[83] R. Ramdani, Marisa, and C. Carudin, "Implementasi Kendali Intensitas Cahaya Lampu dengan Internet Of Things Berbasis Arduino Uno menggunakan Metode Fuzzy Logic," *J. Teknol. Terpadu*, vol. 7, no. 1, pp. 51–58, 2021, doi: 10.54914/jtt.v7i1.273.

[84] M. Peslinof, M. F. Afrianto, Suparman, and Samsidar, "Perancangan sistem pengontrolan temperatur pada alat penetas telur otomatis," *J. ONLINE Phys.*, vol. 4, no. 2, pp. 20–24, 2019.

[85] M. Grossi and M. Omaña, "Accuracy of NTC Thermistor Measurements

Using the Sensor to Microcontroller Direct Interface †," in *Electronic Conference on Sensors and Applications*, 2024.

[86] M. Sasakura, H. Inayoshi, and A. Monden, "Porting a Python Application to the Web Using Django : A Case Study of an Archaeological Image Processing System," 2024. doi: 10.1109/SERA61261.2024.10685556.

[87] I. E. Maulani, I. Azis, and M. N. Cahya, "IMPLEMENTATION OF OBJECT-ORIENTED PROGRAMMING WITH PYQT : DEVELOPMENT OF," *J. Res. Comunity Serv.*, vol. 5, no. 1, pp. 156–163, 2024.

[88] A. Mumuni and F. Mumuni, "Data augmentation: A comprehensive survey of modern approaches," *Array*, vol. 16, no. August, p. 100258, 2022, doi: 10.1016/j.array.2022.100258.

[89] K. Tona *et al.*, "Chicken Incubation Conditions: Role in Embryo Development, Physiology and Adaptation to the Post-Hatch Environment," *Front. Physiol.*, vol. 13, no. May, pp. 1–15, 2022, doi: 10.3389/fphys.2022.895854.

[90] R. M. Noiva, A. C. Menezes, and M. C. Peleteiro, "Influence of temperature and humidity manipulation on chicken embryonic development," *BMC Vet. Res.*, vol. 10, no. 1, pp. 1–10, 2014, doi: 10.1186/s12917-014-0234-3.

[91] S. Yalçin and E. O. Oviedo-Rondón, "Editorial: Avian incubation conditions: Role in embryo development, physiology and adaptation to the post-hatch environment," *Front. Physiol.*, vol. 14, no. January, pp. 1–2, 2023, doi: 10.3389/fphys.2023.1130982.

[92] O. J. Alabi, J. W. Ng'ambi, D. Norris, and M. Mabelebele, "Effect of Egg Weight on Hatchability and Subsequent Performance of Potchfstroom Koekoek Chicks," *Asian J. Anim. Veterunary Adv.*, vol. 7, no. 8, pp. 718–725, 2012.

[93] D. Banaszewska, A. Kasianiuk, B. Biesiada-Drzazga, and U. Zaremba, "Development of Chicken Embryos in Double-Yolk Eggs : Embryonic Mortality," *Animals*, vol. 13, no. 2931, 2023.

[94] F. Khusnawati, P. B. Pramono, M. Sihite, and R. Kusumaningrum,

"Pengaruh Umur Induk Ayam Arab Persilangan Ayam Lingnan Terhadap Persentase Susut Bobot Telur, Fertilitas, Daya Tetas, dan Bobot Tetas DOC," *J. Ilmu Ternak Univ. Padjadjaran*, vol. 22, no. 2, p. 102, 2022, doi: 10.24198/jit.v22i2.41705.