The optimization method performed well in this study, but to increase the utility of MBO, it would be better to yield a useful metamodel for predicting the performance of any configuration. A good approach to accomplish this would be to add a preliminary step to condition the design space. In contrast to an initial zero mean throughout, a far better prior for the Gaussian process can be constructed by using a low-fidelity model based on the lift and drag simulations of the base fixed-wing drone. A concluding step may also be considered where wind tunnel experiments further explore the promising optimization results, reducing the impact of numerical errors in the CFD simulations.

To increase the SLT hybrid drone's flight endurance, it can be better to also hybridize its power system. By utilizing combustion engines, high energy-density fuel can significantly improve the performance when the UAV is properly designed, with the electrical system still being used for redundancy, quick response, and possible solar power integration. Also, variable-pitch propellers may be used to increase the efficiency of the aircraft. By leveraging multiple ways to increase the endurance, a drone can remain in flight for exceptionally long periods of time.

ACKNOWLEDGMENT

The authors would like to thank the Philippines' Department of Science and Technology – Science Education Institute (DOST-SEI) and the Engineering Research and Development for Technology (ERDT). The valuable scholarship support aided in the completion of this study.

REFERENCES

[1] M. De Benedetti, F. D'Urso, G. Fortino, F. Messina, G. Pappalardo and C. Santoro, "A fault-tolerant self-organizing flocking approach for UAV aerial survey," Journal of Network and Computer Applications, vol. 96, pp. 14–30, Aug. 2017. doi: 10.1016/j.jnca.2017.08.004

[2] P. Tao, "Design, Prototyping and Autonomous Control of Gasoline-Engine Variable-Pitch Quadcopter," M. Eng. thesis, National University of Singapore, Singapore, Singapore, May 2016.

[3] I. R. Mcandrew, E. Navarro and K. Witcher (2018), "Propeller Design Requirements for Quadcopters Utilizing Variable Pitch Propellers," International Journal of Materials, Mechanics and Manufacturing, vol. 6(1), pp. 51-56, Feb. 2018. doi:10.18178/ijmmm.2018.6.1.346

[4] D. Zorbas, L. D. P. Pugliese, T. Razafindralamb and F. Guerriero, "Optimal drone placement and cost-efficient target coverage," Journal of Network and Computer Applications, vol. 75, pp. 16–31. Aug. 2016. doi: 10.1016/j.jnca.2016.08.009

[5] P. G. Sai, C. S. Rani and U. R. Nelakuditi, "Implementation of Power Optimization Technique for UAVs," in PMME 2016 Implementation, 2018, paper 5, pp. 132–137. doi: 10.1016/j.matpr.2017.11.063

[6] W. Lu, D. Zhang, J. Zhang, T. Li and T. Hu, "Design and Implementation of a Gasoline-electric Hybrid Propulsion System for a Micro Triple Tilt-rotor VTOL UAV," in 2017 IEEE 6th Data Driven Control and Learning Systems Conference, 2017, pp. 433–438. doi:10.1109/DDCLS.2017.8068112

[7] E. Cetinsoy, S. Dikyar, C. Hancer, K. T. Oner, E. Sirimoglu, M. Unel and M. F. Aksit, "Design and construction of a novel quad tilt-wing UAV," Mechatronics, vol. 22(6), pp. 723–745, May 2012. doi: 10.1016/j.mechatronics.2012.03.003

[8] M. Hochstenbach, C. Notteboom, B. Theys and J. De Schutter, "Design and Control of an Unmanned Aerial Vehicle for Autonomous Parcel Delivery with Transition from Vertical Take-off to Forward Flight - VertiKUL , a Quadcopter Tailsitter," International Journal of Micro Air Vehicles, vol. 7(4), pp. 395–406, Dec. 2015. doi:10.1260/1756-8293.7.4.395

[9] S. Carlson, "A Hybrid Tricopter/Flying-Wing VTOL UAV," in 52nd Aerospace Sciences Meeting, 2014, paper 2014.0016, pp. 1–11. doi:10.2514/6.2014-0016

[10] P. T. Dewi, G. S. Hadi, M. R. Kusnaedi, A. Budiyarto and A. Budiyono, "Design of Separate Lift and Thrust Hybrid Unmanned Aerial Vehicle," The Journal of Instrumentation, Automation and Systems, vol. 2(2), pp. 45-51, Oct. 2015. doi:10.13140/RG.2.1.4900.9681

[11] ArduPilot. (2016) QuadPlane Overview. [Online]. Available: http://ardupilot.org/plane/docs/quadplane-overview.html

[12] L. W. Traub, "Range and Endurance Estimates for Battery-Powered Aircraft," Journal of Aircraft, vol. 48(2), pp. 703–707, Apr. 2011. doi:10.2514/1.C031027

[13] F.G. Ng and A. Chua, "Simulating the Effect of Non-Axial Airflow on the Motion of an Undriven Propeller," International Journal of Advanced Trends in Computer Science and Engineering, vol. 9(1), pp. 153-159, Feb. 2020. doi:10.30534/ijatcse/2020/23912020

[14] Autodesk Inc. (2020) Fusion 360 free 3D CAD/CAM design software for students, educators, and academic institutions. [Online]. Available: https://www.autodesk.com/products/fusion-360/students-teachers-educators

[15] R. Czyba, M. Lemanowicz, Z. Gorol and T. Kudala, "Construction Prototyping, Flight Dynamics Modeling, and Aerodynamic Analysis of Hybrid VTOL Unmanned Aircraft," Journal of Advanced Transportation, vol. 2018(7040531), pp.1-15, Oct. 2018. doi:10.1155/2018/7040531

[16] Autodesk Inc. (2020) CFD Ultimate. [Online]. Available: https://www.autodesk.com/education/free-software/cfd-2

[17] F. Menter, "Review of the shear-stress transport turbulence model experience from an industrial perspective," International Journal of Computational Fluid Dynamics, vol. 23(4), pp. 305-316, Jan. 2009. doi:10.1080/10618560902773387

[18] Federal Aviation Administration, Pilot's handbook of Aeronautical Knowledge: Aerodynamics of Flight. Federal Aviation Administration, 2016.

[19] The GPyOpt authors. (2016) GPyOpt: A Bayesian Optimization framework in Python. [Online]. Available: https://github.com/SheffieldML/GPyOpt

[20] M. Halstrup, "Black-box optimization of mixed discrete-continuous optimization problems" Dr. rer. nat. thesis, TU Dortmund University, Dortmund, Germany, Jul. 2016.

[21] M. Osborne, "Bayesian Gaussian Processes for Sequential Prediction, Optimisation and Quadrature," Ph. D. thesis, University of Oxford, Oxford, England, Mar. 2010. doi:10.1128/JVI.78.14.7590-7601.2004

[22] D. R. Jones, M. Schonlau and W. J. Welch, "Efficient Global Optimization of Expensive Black-Box Functions," Journal of Global Optimization, vol. 13, pp. 455–492, Jun. 1998. doi:10.1023/A:1008306431147

[23] J. González, Z. Dai, P. Hennig and N. Lawrence, "Batch bayesian optimization via local penalization" in Proceedings of the 19th International Conference on Artificial Intelligence and Statistics, 2016, pp. 648–657.

[24] N. S. Dige, "Efficient Sampling Algorithm for Optimization under Uncertainty," M. Sc. thesis, University of Illinois. Chicago, Illinois, Jun. 2016.