CURRENT RESEARCH IN
COMPUTER SCIENCE
ISSN 2788-7707
JUN. 2022 VOL. 2, NO. 1

A UAV Dynamics Model Based on Machine Learning

Yaffa Himmat

Department of Statistics & Computer Science, University of Kelaniya, Sri Lanka

ABSTRACT

The developed machine learning based drone dynamic model works at a fraction of real-time with 2.3GHz CPU for a given recorded radio controller data set of a figure of eight trial. The high-level shape comparison between the actual pattern and predicted pattern is at a satisfactory level. However the shape of the predicted path is closer to the shape of a lace eight and there are many predicted points are not in the required figure of eight pattern. It may due to the data preprocessing techniques, minute effect of the wind or the used machine learning technique. Carried out experiments provide encouraging results to further experiments and validations to clarify the impacts of deploying Figure of eight maneuvering pattern or its derivative to collect data and built machine learning based drone dynamic model.

KEYWORDS

Done; Simulation; Machine learning; Maneuvering.

1. Introduction

There are few commercial drone simulators and those simulators can be used to simulate particular commercial drone such as 3DR Solo, AR.Drone and DJI Phantom (Spark Pilots 2018) (DJI 2018). There are many proposed generalized drone dynamic simulation models and most of these models are based on Newtonian dynamics and fluid dynamics (Wang , et al. 2016), (Parrot SA 2018). However, using these existing generalized drone dynamic simulation models and simulation of real world drone pilot drill is not straightforward. There are many challenges to overcome.

If machine learning based proven approach is exists to simulate drones then it can be used to simulate given real drone in a virtual environment. Hence, proposing a machine learning based approach to simulate real world drone dynamic model with appropriate realism is a potential solution to avoid above mention issues in existing generalized Newtonian dynamics and fluid dynamics based drone simulation models. There are commonly used vehicle maneuvering patterns in domains such as aviation, maritime. This reported work explored the potential of use identified commonly used vehicle maneuvering pattern and collect drone behavior data and user interaction data to built machine learning based drone dynamic model.

2. Related Work

Pengcheng. Wang et al proposed a Dynamics modeling and linear control of drone (Wang , et al. 2016). Camilo Andrés et.al proposed a Simulation, Model and Control of a Quadcopter AR Drone 2.0 (Flórez, Amaya and Rosário 2016). They proposed a mathematical model, control and simulation of aerial robot AR Drone 2.0 (Parrot SA 2018). Francesco Sabatino prosed and tested a mathematical model of a drone dynamics using Newton's and Euler's laws (Sabatino 2015). The behavior of the drone under the proposed control strategies is observed in virtual reality by using the Matlab Simulink 3D. These Newtonian dynamic and fluid dynamic based mathematical/ Physical based models consist of many model parameters and require specific working conditions or controlled environments. If we select existing generalized drone dynamic simulation model and try to simulate existing drone under real-world conditions then there are many issues such as estimation of model perimeters of the drone dynamic model and difference conditions between real-world and ideal conditions recommended in the Newtonian dynamic and fluid dynamic based dynamic models.

There are commercial simulators that can be used for simulation of drones. The DJI Assistant 2 software is a drone simulation provided by DJI and it can be used to simulate selected the DJI drones (Spark Pilots 2018) (DJI 2018) . The DJI Assistant 2 can be programmed to simulate drones with offline remote control data. RealFlight drone/flight simulator (Horizon Hobby, LLC. 2018), Simpro drone simulator (DroneSim Pro 2019), Liftoff by Immersion RC (Immersion RC 2019) and HELI-X professional R/C flight simulator (Heli-x 2015) are some of the reviewed commercial drone simulators which can be employed to simulate particular commercial drone.

Peter T. Jardine et al proposed machine learning based approach to approximate at hovering of the drone (Jardine, Givigi and Yousefi 2017). They used a machine learning scheme that has been applied to adaptive control in random, uncertain environments. Their goal is to increase the tracking performance of the drone. Furthermore, a comparison with previous work demonstrates improved tracking performance.

Jemin Hwangbo et al presented a method to control a quadrotor with a neural network trained using reinforcement learning techniques (Hwangbo , et al. 2017). They demonstrated the performance of the trained policy both in simulation and with a real quadrotor. The trained policy shows outstanding performance and remains computationally cheap at the same time and it shows many other advantages of neural network policies that are not limited to their versatility. This experiment is limited to small space which approximately covers 2m x 2m x2m controlled area

Osman Çakira and Tolga Yükselb (Çakira and Yükselb 2017) developed neural network based controller for of quadrotors. In this study, neural network control of quadrotors is aimed to obtain an artificial intelligence based controller and the results shows that neural network controllers achieve satisfactory trajectory tracking results. This experiment is also limited to small space which approximately covers 5m x 3m x3m controlled area.

As discussed above, there are approaches to simulate drone dynamics with machine learning based approaches. However, these research work and related experiments were conducted under indoor controlled environment and focused on a part of the dynamic model.

Commonly Used Vehicle Maneuvering Patterns

Ground vehicle driver training is has over two hundred years of history and it began as a real form of a commercial venture in Great Britain about 1909-10 (Russell 2002). The pilot training and aviation education began early in the 20th century after the Wright brother's successful invention of the first airplane (Barata and

Neves 2017). Naval training and education existed for more than 300 years and it has great records with the time (Wikipedia 2019). Teaching and learning procedures of all of these domains were greatly enhanced with the time and technological innovations. Similar type of trials and tests are used in automobile industry, shipbuilding and aircraft manufacturing industry. There is a vast theoretical knowledge, practical knowledge and know how in these developed knowledge basses with proven track records. Navel training, pilot training and ground vehicle training all used context specific maneuvering drills for their teaching and learning processers.

In pilot training there are commonly used fundamental maneuvers such as Steep power turns, Steep spirals about a point, Chandelle turns, Lazy eights and Eights-on-pylons or pylon eights (Federal Aviation Administration 2016) (Flight Training Centers 2019).

Figure 1 illustrates the maneuvering pattern of Eights-on-pylons or pylon eights.

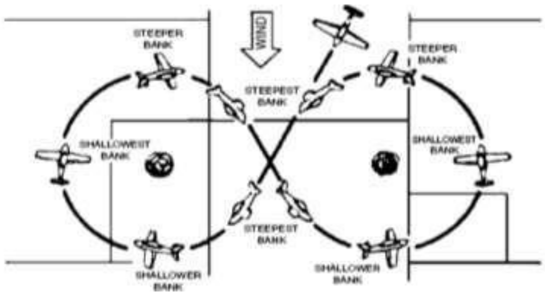

Figure 1. Eights-on-pylons or pylon eights (Pilot Online 2019)

In naval training and ship building, there are standers maneuvering test such as Turning circle maneuver, Z-maneuver , Direct spiral maneuver, Stopping test and Parallel course maneuver. (ITTC 2002) (IMO 2002). Figure 2 Illustrates the maneuvering pattern of Eights-on-pylons or pylon eights. Figure 1 Illustrates the pattern of aTurning circle maneuver.

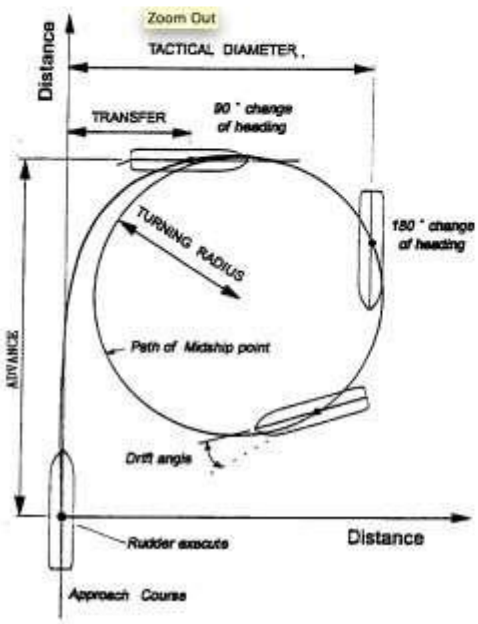

Figure 2. Pattern of a ship’s turning circle maneuver (IMO 2002)

Similarly, in the ground vehicle driver and motorbike rider training procedures consists of many drills such as Figure of eight driving or riding (Thanhniennews 2013) (AutomatedDriving 2013). In the automobile industry, many testing and trials are performed with the Figure of eight driving pattern (Stanford Engineering 2018). Figure 3 presents the driver-testing track of transport Department of Government of Gujarat (AutomatedDriving 2013).

Figure 3. Driver testing track of transport Department, Gujarat (AutomatedDriving 2013).

Due to the technology development and commercial potential of drones, drone pilot training became a requirement (PwC Belgium 2018), (Drone Pilot Ground School 2018). Sets of drone pilot training drills were proposed and practiced by many aviation authorities, pilot training institutes such as British Model Flying Association, DronePartners Ltd (DronePartners 2018), UAV Coach (UAV Coach 2018), Drone Pilot Ground School (Drone Pilot Ground School 2018). Figure 4 Illustrates the basic arrangement of Lazy eight and the Figure of eight drone pilot drills (Drone Partners Ltd 2018).

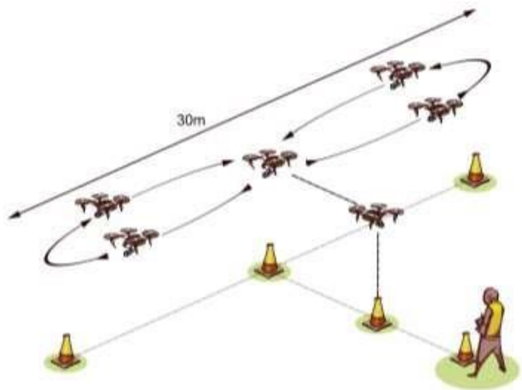

Figure 4. Arrangement of Lazy eight drone pilot drill (Drone Partners Ltd 2018).

Most of the above discussed maneuverability test or drills involve with Six degrees of freedom (6DoF) movements of a body (Vehicle, ship, flight or drone) with respect to the dynamic user interaction. All these maneuverability test or drills involve with the most of the key maneuverability behaviors of the respective vehicle type. Figure of eight maneuvering pattern or its derivative is used in all above discuss scenarios.

3. Experimental Procedure and Results

Figure of eight maneuvering pattern was selected to be employed in the data collection process and built the machine learning based drone dynamic model. Experienced done pilot was selected and many Figure of eight maneuvering pattern with DJI Phantom drone. All maneuvering trials were conducted under calm environment with minute wind conditions. As shown in the Figure 5, the actual shape of the flying track in the form of Figure of eight and actual dimensions of the track has width of 24 m and length of 60 m. Selected experienced done pilot preformed the drills by looking at the Figure of eight shape marked on the university ground. As shown in the Figure 6, done pilot used first person view of the drone via a live video stream captured from camera mounted on the DJI Phantom. Figure 7 presents the actual aerial view of a sample drone pilot drill.

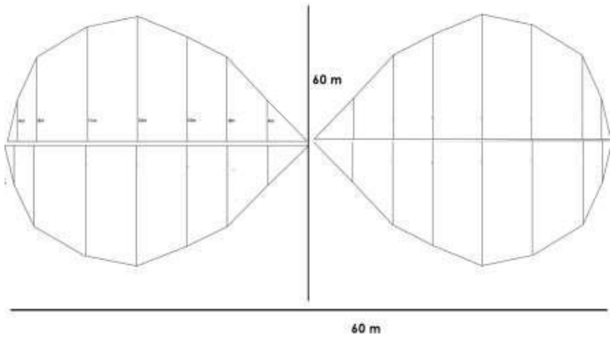

Figure 5. Actual dimensions of the flying track of the drone

Figure 6. First person view of the drone via a drone camera

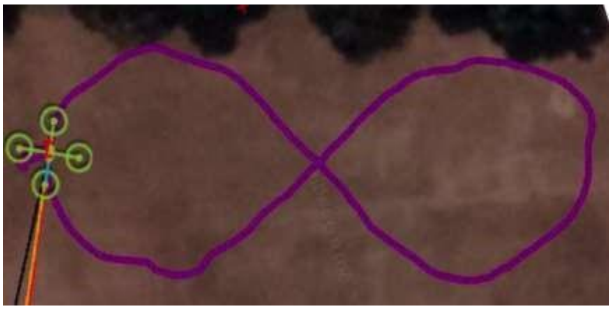

Figure 7. Actual aerial view of a sample drone pilot drill

Recorded data can be categorized to two main categories as given below:

- Drone pilot inputs entered via the drone Radio Controller (RC) and it represents the given inputs such as throttle and rudder values that are responsible for the drone position and orientation changes.
- Drone's position and orientation changes with the time and other relevant sensor information vary with the time (Eg: Battery level, accelerations, velocities)

After collecting the raw data, preprocessing methods and tools were used to extract the required data and selected key parameters of the above sample data set are described below:

Time(seconds) - Time elapsed since the power up
Battery Voltage - Total voltage of four cells of the battery
RcAileron - Rc signals for roll
RcElevator - Rc signals to control the horizontal pitch attitude of the drone.

RcRudder - Rc signals to control the yaw of the drone
RcThrottle - Rc signals control the speed of the engine and hence how fast or slow the movement of the drone.
x,y,z - Cartesian conversion of Longitude and Latitude
Orientation - Bearing of the head of the drone in degrees

As explained above, a machine-learning model was built using time stamp, radio controller commands, battery voltage, position and the orientation data of the drone. The developed machine-learning model is based on regression and multiple target variables concept. Recorded radio controller data set of a figure of eight trial is given to the developed machine-learning model and observed the predicted position and orientation of the drone. Following figure 8 illustrate the shape of the predicted path of the drone.

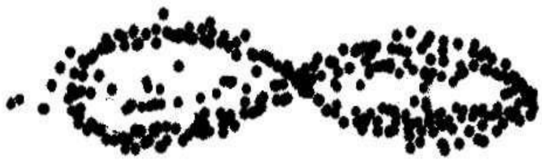

Figure 8. Shape of the predicted path of the drone

4. Future Work and Conclusions

The developed machine learning based drone dynamic model works at a fraction of real-time with 2.3GHz CPU for a given recorded radio controller data set of a figure of eight trial. The high-level shape comparison between the actual pattern and predicted pattern is at a satisfactory level. However the shape of the predicted path is closer to the shape of a lace eight and there are many predicted points are not in the required figure of eight pattern. It may due to the data preprocessing techniques, minute effect of the wind or the used machine learning technique. Carried out experiments provide encouraging results to further experiments and validations to clarify the impacts of deploying Figure of eight maneuvering pattern or its derivative to collect data and built machine learning based drone dynamic model.

References

Flight Training Centers. "Commercial Manuevers." Flight Training Centers. 2019. https://flighttrainingcenters.com/training-aids/commercial/commercialmanuevers/ (accessed 2019).

Flórez, Camilo Andrés Cáceres , Dario Amaya, and João Maurício Rosário. "Simulation, Model and Control of a Quadcopter AR Drone 2.0." International Review of Mechanical Engineering (Praise Worthy Prize), May 2016.

Microsoft . "Microsoft shares open source system for training drones, other gadgets to move safely on their own." www.blogs.microsoft.com. 2017. https://blogs.microsoft.com/ai/microsoft-shares-open-source-system-trainingdrones-gadgets-move-safely/.

Çakira, Osman, and Tolga Yükselb . "Neural Network Control for Quadrotors." American Scientific Research Journal for Engineering Technology, and Sciences (ASRJETS) (Global Society of Scientific Research and Researchers) 31 (2017).

AutomatedDriving. "English 8 Track Test." AutomatedDriving. ransport Department of Government of Gujarat. 2013. https://www.youtube.com/watch?v=cYjOSmyvHM4 (accessed 2019).

Barata , Jorge M M, and Fernando M S P Neves . "The History of Aviation Education and Training." Open Journal of Applied Sciences (Scientific Research Publishing Inc) 7, no. 4 (2017).

Colyer, Roland Moore. "Microsoft Makes Its Drone AI Training Simulator Kit Available As Open Source Software." www.silicon.co.uk. 2017. http://www.silicon.co.uk/software/open-source/microsoft-ai-training205685?print=pdf&inf_by=5a92b042681db8be028b4d86.

Consortiq Ltd t/a UAVAir. "Drone pilot career – expected earnings and opportunities." Start your journey to become a professional drone pilot today. 2018. https://uav-air.com/news/uavair-news/drone-pilot-career-expected-earningsopportunities.

Drone Partners Ltd. "DronePartners." Straight ForwardDrone Manoeuvres. Drone Partners Ltd. 2018. https://dronepartners.co.uk/wp-content/uploads/2018/01/Straight-Forward-Drone-Manoeuvres-v1.0.pdf (accessed 2019).

Drone Pilot Ground School. Drone Pilot Ground School Curriculum. 2018. https://www.dronepilotgroundschool.com/curriculum/.

Federal Aviation Administration. Airplane Flying Handbook . Vol. 1. 1 vols. U.S. Department of Transportation (DOT), Federal Aviation Administration, 2016.

Heli-x. Professional R/C Flight Simulation . 2015. https://www.heli-x.info/cms/ (accessed 2019).

Hoffma, William. Drones Will Need Air Traffic Control, Stanford and NASA Will Build It. Inverse Innovation. 2016. https://www.inverse.com/article/13951-droneswill-need-air-traffic-control-stanford-and-nasa-will-build-it.

Horizon Hobby, LLC. RealFlight 8. Horizon Hobby Edition. 2018. https://www.realflight.com/ (accessed 2019).

Hwangbo , Jemin , nkyu Sa , Roland Siegwart , and Marco Hutter . "Control of a Quadrotor with Reinforcement Learning ." IEEE Robotics and Automation Letters. 2017. 2096-2103.

Immersion RC. LIFTOFF – The Drone Race Simulator. 2019. https://www.immersionrc.com/fpv-products/liftoff-drone-race-simulator/ (accessed 2019).

IMO. "Explanatory notes to the Standards for ship manoeuvrability." International Maritime Organization. 2002. http://www.maritimeconsultant.com/ships%20maneuvability.pdf (accessed 2019).

ITTC. "ITTC Full Scale Measurements Manoeuvrability Full Scale Manoeuvring Trials Procedure." Welcome to ITTC -The International Towing Tank Conference. 2002. https://ittc.info/media/2131/75-04-02-01.pdf (accessed 2019).

Jardine, Peter T, Sidney Givigi, and Shahram Yousefi. "Parameter Tuning for Prediction-based Quadcopter Trajectory Planning using Learning Automata." Edited by Didier Henrion, Dimitri Peaucelle Denis Dochain. 20th IFAC World Congress. 2017.

Kelley, Tiffany. "The Booming Demand for Commercial Drone Pilots ." The Atlantic Daily, free weekday newsletter. 2017. https://www.theatlantic.com/technology/archive/2017/01/drone-pilotschool/515022/.

PwC Belgium. A drone's eye view. Report, PricewaterhouseCoopers International Limited (PwCIL), PwC Belgium and Agoria vzw/asbl, 2018.

Russell, Peter. "A Brief History of Driver Education in the UK." Driver Education Research Foundation - DERF. Driver Education Research Foundation (UK). 2002. http://derf.org.uk/history.htm (accessed 2019).

Sabatino, Francesco. Quadrotor control: modeling, nonlinear control design, and simulation. Master's Thesis, Electrical Engineering, KTH Royal Institute of Technology, Stockholm, Sweden: KTH Royal Institute of Technology, 2015.

Spark Pilots. "Dji Assistant 2 ver 1.1.2." Spark Pilots. 2018. https://sparkpilots.com/threads/dji-assistant-2-ver-1-1-2.11976/ (accessed 2019).

Thanhniennews. "Thanhniennews." The passion of Vietnamese Driver's License. 2013. http://www.thanhniennews.com/commentaries/the-passion-of-vietnamesedrivers-license-1942.html (accessed 2019).

UAV Coach. UAV Coach. 2018. https://uavcoach.com/.

Wang , Pengcheng , Zhihong Man , Zhenwei Cao , Jinchuan Zheng , and Yong Zhao . "Dynamics modelling and linear control of quadcopter." International Conference on Advanced Mechatronic Systems . Melbourne: IEEE , 2016. 498503.

Wikipedia. "Royal Danish Naval Academy." Wikipedia, the free encyclopedia. 2019. www.fak.dk/om/organisation/Pages/SoeværnetsOfficersskole.aspx (accessed 2019).