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Table of contents

Volume 55
Number 1, January 2020
‹ Previous issue Next issue ›

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Paper

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Editorial Board

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Learning vector of motion using FlightRadar24 and Tracker motion analysis

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Abstract
The vector of aircraft motion and analysis using **FlightRadar24** and Tracker motion analysis has been investigated and studied. The straight, turning and circular aircraft motion were recorded from www.flightradar24.com using a commercial desktop video recording. Then, the video of the aircraft motion was analyzed using Tracker 5.1.1 to determine the position versus time relation ($X(t)$, $Y(t)$). The straight aircraft motion observations show that we can learn (or teach) the concept of vectors from a position versus time relation data ($X(t)$, $Y(t)$). From observations of turning aircraft motion, we can study changes in vectors of velocity and angles between two vectors. Also, from the circular aircraft motion observation, we can learn the concepts of radius, period, and speed of circular motion. This research is expected to improve the quality of physics learning by presenting exciting and flexible experiments for students, teachers, and instructors.

Introduction

Kinematics is the main topics taught in the physics curriculum in schools or universities. The concept of kinematics is a crucial topic in the application of physics in the engineering field [1]. Previous studies found that most students had difficulty in connecting the concept of kinematics with graphical representation (abstraction), especially in the position coordinates versus time, the vector of velocity or vector operation. Thus, many previous studies have investigated the kinematic motion of objects to improve teaching quality in this topic [2–4].

The interesting and widely method used for analyzing the kinematics of object motion is high-speed video analysis [5–7]. The use of high-speed camera analysis methods has increased rapidly because the technology is quite precise, easy, and inexpensive [6, 7]. This method allows teachers, instructors, and students to record and study the motion of objects in a real, actual, and realtime situation [7]. Many studies have examined various phenomena of real-body kinematics motion as well as game applications on smartphones using high-speed video analysis techniques [3, 5], and used them to improve the quality of physics teaching. However, no research analyzes the kinematics motion of real objects that obtain online. The kinematics motion of real objects and that which can get online is the aircraft motion on the www.flightradar24.com. The www.flightradar24.com is a global aviation digital map service that provides the realtime route, position, aircraft speed, and other information about thousands of commercial aircraft around the world [8].

The objectives of this study are (1) to record some aircraft kinematics motion (straight, turning and circular motion) and analyze them using high-speed video; (2) to provide graphical evidence to understanding the concept of vectors of velocity and angles between two vectors obtained from position data of the aircraft; (3) and to learning of the concept of radius, period, and speed of aircraft circular motion. The observation of aircraft motion is interesting because there are several kinematics concepts, vector concepts, and mathematical operations that can be explored or studied in the school or university.

Methods

In general, the observations of the aircraft motion consist of: (a) taking aircraft motion videos from www.flightradar24.com and (b) video motion analysis using Tracker 5.1.1 for straight, turning and circular motion.

Video recording of aircraft motion

The video recording of aircraft motion consists of: (i) opening page of www.flightradar24.com, (ii) searching for commercial Airport (such as Husein Sastranegara Airport, Bandung—Indonesia, www.flightradar24.com/LN1904/f2ab8a0); it will show the flight departure and arrival schedule. (iii) looking for a Aircraft that is crossing in a specific area, then watching the Aircraft motion carefully to choose the straight, turning or circular motion such as shown at figure 1. (iv) Clicking the Aircraft; the color changes to red and the departure schedule information, the airport destination, as well as a graph of the aircraft's speed and position. (v) Then, recording the motion of the aircraft using the oCam or QuickTime software for Windows or Macbook (http://ohsoft.net/eng/ocam/download.php?cate=1002 or https://support.apple.com/kb/dl923), and taking the video recording in the oCam or QuickTime folder.

Video motion analysis

The straight, turning and circular motion of the aircraft from www.flightradar24.com were analyzed using Tracker 5.1.1 software, as shown in figure 1, free software and guides at www.physlets.org/tracker/. In this study, the standard configuration of video analysis at Tracker 5.1.1 software was used, as shown in figure 2(a). The steps of video analysis of aircraft motion consist of: (i) Put the video file of Aircraft motion, clicking the video file storage (step 1), (ii) setting the coordinate axis (step 2) and placing the x-axis and y-axis in the motion area, (iii) setting the calibration bar in the calibration scale area at the right-bottom area (step 3), (iv) select an observation point by clicking on the new observation logo (step 4), and (v) Aircraft position data ($X(t)$, $Y(t)$) could be obtained manually or automatically (step 5) as shown in figure 2(b). The data processing, graphical, and linear fitting analysis of the position versus time ($X(t)$, $Y(t)$) performed on commercial data processing software.

Trials and results

The observation of straight aircraft motion was conducted to observe and understand the concept of the position and vector of velocity, as shown in figure 3. The results show that aircraft move straight in the 2D cartesian, with height variables ignored. The speed data from www.flightradar24.com shows that the average speed of the aircraft motion is 780 km h^{-1} (see figure 3(a)). Then, to determine and analyze the aircraft's position changes with time ($X(t)$, $Y(t)$), a linear fitting technique for each coordinate was carried out [1, 4], by:

$$(X(t), Y(t)) = (v_x, v_y) \cdot t + (X_o, Y_o) \quad (1)$$

so, obtained the linear fitting equation as follows:

$$X(t) = 0.1884 \cdot t + 0.534 \ \text{(km)},$$
$$Y(t) = -0.105 \cdot t + 8.196 \text{(km)}.$$

With, $v_x = 0.1884\,\text{km}\,\text{s}^{-1}$, $v_y = -0.105\,\text{km}\,\text{s}^{-1}$. Thus, the vector of the velocity of a straight moving aircraft equaled to:

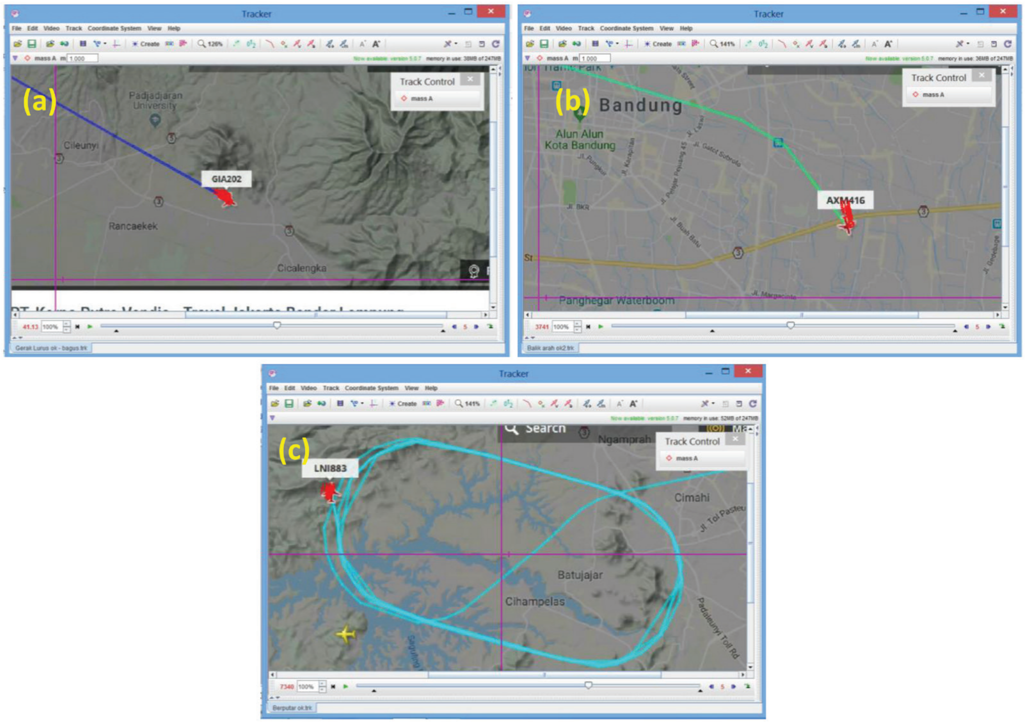

Figure 1. The video recording and analysis for (a) straight, (b) turning, and (c) circular motion of aircraft from www.flightradar24.com using Tracker 5.1.1. Copyright (c) 2019 Douglas Brown.

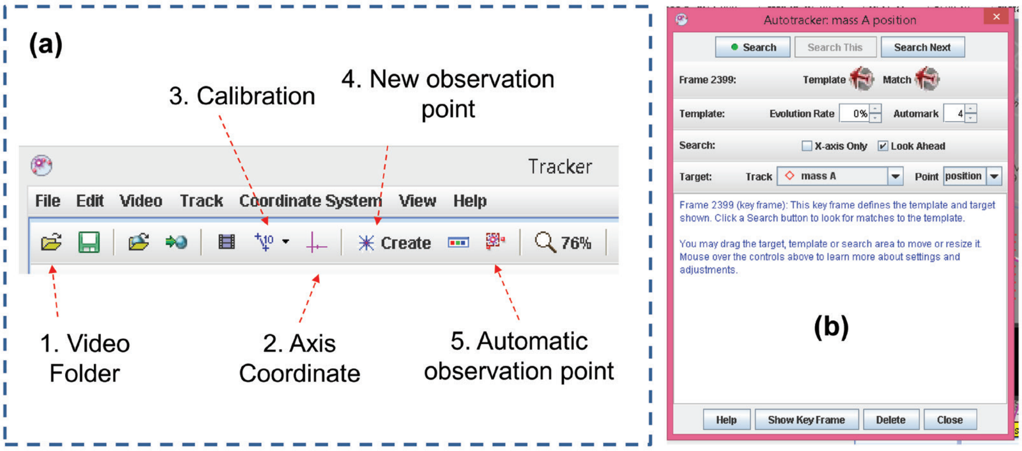

Figure 2. (a) The standard configuration of video analysis at Tracker 5.1.1 software, and (b) the automatic observation point configuration. Copyright (c) 2019 Douglas Brown.

$$\vec{v} = 0.1884\,\hat{i} - 0.105\hat{j}\,(\text{km s}^{-1})$$

$$\vec{v} = 678.24\,\hat{i} - 378\hat{j}\,(\text{km h}^{-1})$$

$$|\vec{v}| = \sqrt{678.24^2 + (-378)^2} = 776.46\,(\text{km h}^{-1})$$

$$\Delta v_{\text{error}} = |776.46 - 780| =\sim 3.54\,(\text{km h}^{-1})\ \text{or}\ 0.45\%.$$

With $X(t)$, $Y(t)$, t, v_x, and v_y are a horizontal axis, vertical axis, time, horizontal speed, and vertical speed, respectively. The results show that the average speed of aircraft motion based on information from www.flightradar24.com (figure 3(a)) and Tracker motion analysis is comparable with a small error (Δv_{error}).

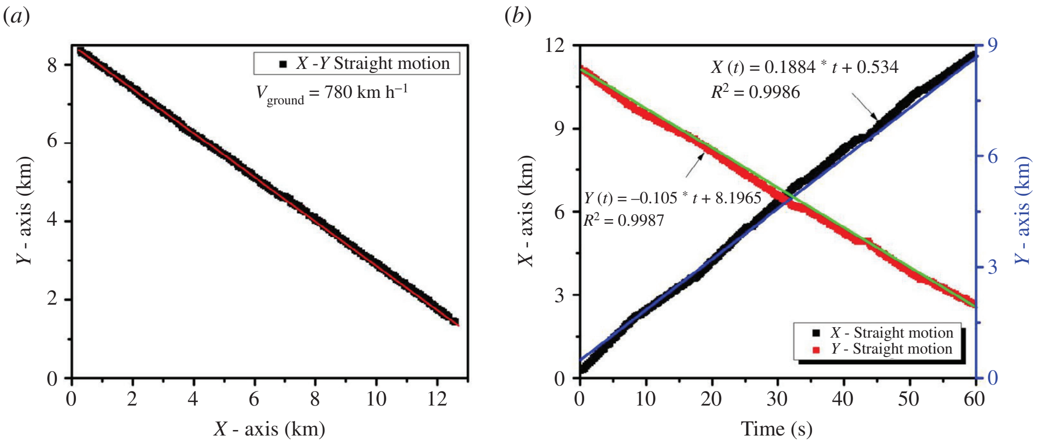

Figure 3. (a) cartesian coordinate (X versus Y) and (b) position versus time relation ($X\,(t)$, $Y\,(t)$) of aircraft straight motion from www.flightradar24.com using Tracker 5.1.1 motion analysis.

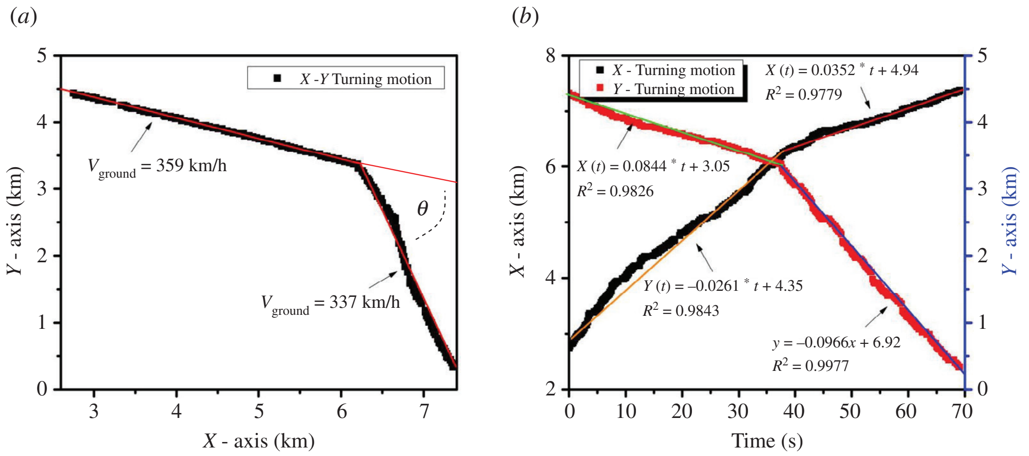

Figure 4. (a) Cartesian coordinate (X versus Y) and (b) position versus time relation ($X\,(t)$, $Y\,(t)$) of aircraft turning motion from www.flightradar24.com using Tracker 5.1.1 motion analysis.

The motion observation of the turning aircraft was carried out to observe changes in the vectors of velocity and the magnitude of the turning angle, as shown in figure 4. The results of the observation show that there is a significant change in the vector velocity in the 2D (see figure 4(a)). Therefore, the observation and analysis of the movement kinematics of objects will be carried out before and after the aircraft turns, then the changes in the oblique angle of the aircraft are analyzed. To determine and analyze the position changes with time ($X(t)$, $Y\,(t)$) a linear technique for each coordinate before and after the turning motion is carried out, such as the following:

$$X_i\,(t) = 0.0844 \cdot t + 3.05\ \text{(km)} \quad \text{and}$$
$$Y_i\,(t) = -0.0261 \cdot t + 4.35\,\text{(km)}.$$

With the vector of the velocity of an aircraft before turning is equal to:

$$\vec{v_i} = 0.0844\,\hat{i} - 0.0261\,\hat{j}\,(\text{km}\,\text{s}^{-1})$$

$$\vec{v_i} = 303.84\,\hat{i} - 93.96\,\hat{j}\,(\text{km}\,\text{h}^{-1}) \quad \text{with}$$
$$|\vec{v_i}| = 318.03\,(\text{km}\,\text{h}^{-1}).$$

While the analysis of changes in position versus time ($X(t)$, and $Y(t)$) of the aircraft after turning is:

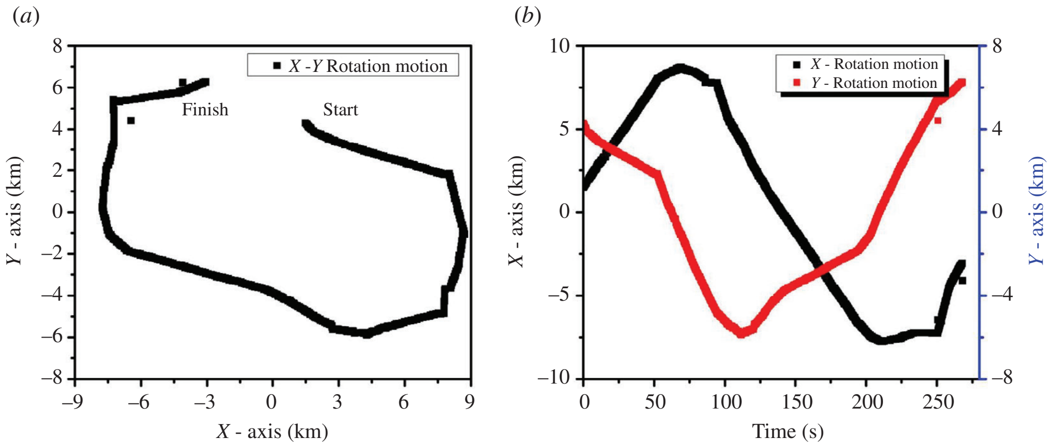

Figure 5. (a) Cartesian coordinate (X versus Y) and (b) position versus time relation ($X(t)$, $Y(t)$) of aircraft circular motion from www.flightradar24.com using Tracker 5.1.1 motion analysis.

$$X_f(t) = 0.0352 \cdot t + 4.94 \quad \text{and}$$
$$Y_f(t) = -0.0966 \cdot t + 6.92$$

so, the vector of the velocity of an aircraft after turning is equal to:

$$\vec{v_f} = 0.0352\,\hat{i} - 0.0966\,\hat{j}\,(\mathrm{km\,s^{-1}})$$

$$\vec{v_f} = 126.72\,\hat{i} - 347.76\,\hat{j}\,(\mathrm{km\,h^{-1}}) \quad \text{with} \quad |\vec{v_f}| = 370.13\,(\mathrm{km\,h^{-1}}).$$

Based on the results above, the magnitude of the turning angle ($\Delta\theta$) of an aircraft can be calculated using the following equation (2) [1]:

$$\vec{v_i} \cdot \vec{v_f} = |\vec{v_i}| \cdot |\vec{v_f}| \cos\Delta\theta, \text{ or } \cos\Delta\theta = \frac{\vec{v_i} \cdot \vec{v_f}}{|\vec{v_i}| \cdot |\vec{v_f}|} \tag{2}$$

the calculation results show that the turning angle ($\Delta\theta$) of the aircraft's motion is 53°.

The third observation was carried out on aircraft circular motion above the Kota Bandung (West Java, Indonesia), as shown in figure 5. The observations show that the aircraft moved to form almost like a 2D circle (or ellipse) pattern (figure 5(a)). Also, the curve analysis of position versus time relation ($X(t)$, $Y(t)$) shows that the one round aircraft motion takes 250–300 s (1 period), with a radius of circular motion about 6–10 km (figure 5(b)). Therefore, the speed of an aircraft circular motion can be calculated using the equation (3) below [1]:

$$v_{\text{rotation}} = \frac{2\pi r}{T}. \tag{3}$$

It shows that the approximate speed of the aircraft circular motion is 600–750 km h^{-1}. However, if the position of the aircraft carefully observed, it can show that the position curve does not have a perfect shape or there is missing data. This because by the process of sending aircraft position data from www.flightradar24.com to computer networks hampered due to slow satellite/internet access, so there is a delay between the website and video recording.

Conclusions

The vector of aircraft motion and analysis using www.flightradar24.com and Tracker 5.1.1 has been investigated and studied. The straight, turning and circular motion of aircraft were video records from www.flightradar24.com using a commercial desktop video recording. Then, the videos of aircraft motion were analyzed using Tracker 5.1.1 to determine the position versus time relation ($X(t)$, $Y(t)$). The straight aircraft motion observations show that we can learn (or teach) the concept of vectors from data changes on a position versus time relation ($X(t)$, $Y(t)$). Meanwhile, from observations of turning aircraft motion, we can study changes in vectors of velocity and angles between two vectors. Also, from the circular aircraft motion observation, we can learn the concepts of radius, period, and speed of circular motion.

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