19 Determination of the Radius of Curves and Roundabouts with a Smartphone

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Based on earlier work [1], this chapter describes two further experiments that can be carried out on the road. It will be explained how to determine the radius of curves and roundabouts of public streets using only a smartphone. The first experiment shows how to determine the radius of a curve by driving a car around the curve while sampling the acceleration data of the car. The second experiment shows how to calculate the radius of a roundabout by using the built-in gyroscope sensor in combination with the acceleration sensor of the smartphone. The same procedure was used by Monteiro et al. (Chap. 18) [2] to examine a merry-go-round.

19.1 Determination of a Curve Radius Using the Acceleration Sensors

For this experiment, the smartphone has to be mounted in the car, in order that the two acceleration sensors are correctly aligned—one in the direction of motion and one orthogonal to the direction of motion. To execute the experiment, start the sampling of the acceleration data while the car is in a standstill position. When the car is at a standstill, accelerate to a certain velocity that permits one to move around the bend at a constant speed and radius. The car, as well as the measurement, can be stopped once the curve has been passed. In the following graph you can see the acceleration data as a function of time (Fig. 19.1).

By integrating the acceleration data in the direction of motion over time, you obtain the velocity graph of the car as a function of time (Fig. 19.2).

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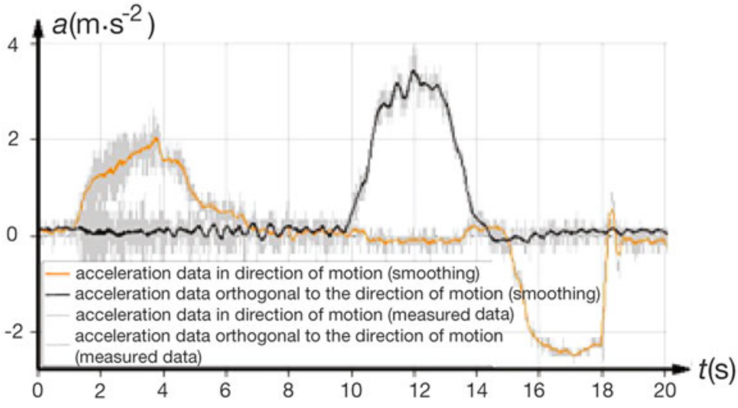

Fig. 19.1 The acceleration data as functions of time

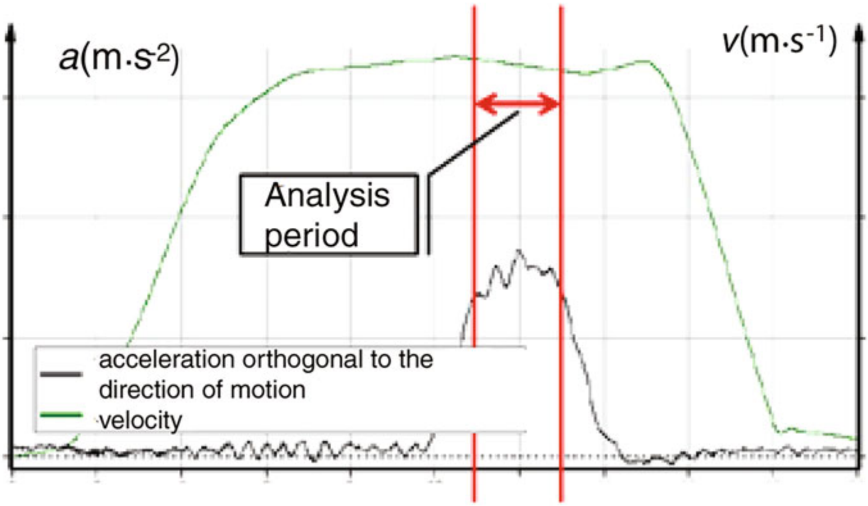

Fig. 19.2 The velocity of the car and the acceleration data orthogonal to the car as functions of time

The relation between velocity and orthogonal acceleration (centripetal acceleration) of a constant circular motion allows us to determine the radius of the curve:

$$a_c = \frac{v^2}{r}$$

(a_c = orthogonal acceleration, v = velocity of the car, r = radius of curve). The following section shows the result of three consecutive measurements including the standard errors of the average means:

Fig. 19.3 Google Maps overview of the curve used in this experiment

$$r_1 = (14.1 \pm 0.1)\text{m},\ \ r_2 = (14.6 \pm 0.1)\text{m},\ \ r_3 = (13.61 \pm 0.12)\,\text{m}.$$

The analysis of the curve via Google Maps yields to a radius of 13.7 m and hence agrees with the values determined by the experiment (Fig. 19.3).

19.2 Determination of the Radius of a Roundabout Using the Acceleration Sensor in Combination with the Gyroscope Sensor

For this experiment, the smartphone has to be aligned in the direction of movement. Afterwards, you sample the data of the gyroscope and acceleration sensor simultaneously while driving around a roundabout with constant speed and radius (Fig. 19.4).

The relation between centripetal force and angular velocity allows the calculation of the radius of the roundabout (Fig. 19.4):

$$r = \frac{a}{\omega^2}$$

(r = radius, a = centripetal acceleration, ω = angular velocity). Two consecutive measurements lead to the following results

$$r_1 = (11.42 \pm 0.01)\ \text{m},\ \ r_2 = (11.789 \pm 0.019)\ \text{m}.$$

The analysis of the curve via Google Maps yields to a radius of 11.2 m (see Fig. 19.5). Again, the values of the experiment are consistent with the theoretical values determined by the analysis of the roundabout via Google Maps.

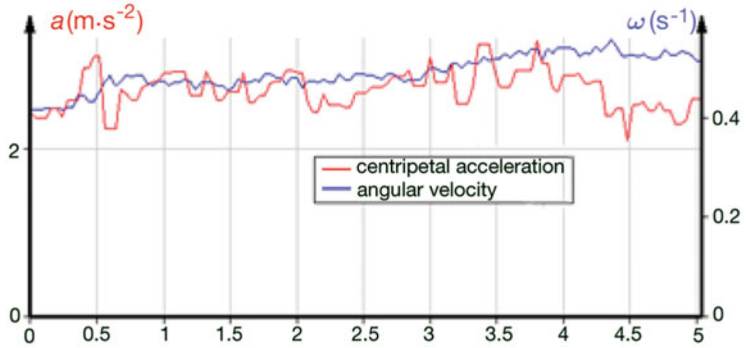

Fig. 19.4 The centripetal acceleration and angular velocity as functions of time

Fig. 19.5 Google Maps overview of the roundabout used in this experiment

Finally it can be concluded that with the two presented methods, curve radii can be determined with sufficient accuracy for educational purposes.

References

1. Fahsl, C., Vogt, P.: Determination of the drag resistance coefficients of different vehicles. Phys. Teach. **56**, 324–325 (2018)
2. Monteiro, M., Cabeza, C., Marti, A.C., Vogt, P., Kuhn, J.: Angular velocity and centripetal acceleration relationship. Phys. Teach. **52**, 312–313 (2014)