Physics experiments using simultaneously several smartphone sensors

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In the last years, numerous Physics experiments using smartphone sensors have been reported in the literature. In this presentation we focus on a less-explored feature of the smartphones: the possibility of using (measure and register data) simultaneously with more than one sensor. To illustrate, in the field of mechanics simultaneous use of the accelerometer and gyroscope (angular velocity sensor) or in optics experiments synchronous use of the ambient light and orientation sensors have been proposed. Indeed, this is a characteristic that simplifies experimental setups allowing to see through the physics concepts and, last but not least, reducing the costs.

1 Introduction

Recently, numerous smartphone-based physics experiments have been proposed in the literature [1,2]. These experiments take advantage of the built-in smartphone sensors as the accelerometer, gyroscope (angular velocity sensor), magnetometer, proximeter, luxometer (ambient light), pressure (barometer) among others. Usually, only one sensor is used in each experiment. Remarkably, smartphones also gives us the ability to measure simultaneously with various sensors. This is a great benefit since it allows to perform a great deal of experiments, even outdoors, avoiding the dependence on delicate and expensive instruments. As we consider that this capability has not been fully exploited, in this presentation we discuss some experiments involving the use of more-than-one smartphone sensor and, at the end, present some perspectives.

2 Simultaneous use of the more than one smartphone sensors

As far as we know, in the first Physics experiment in which more than one sensor was used a smarpohne was placed on the floor of a merry-go-round at different distances from the rotation shaft [3]. In this experiment, the acceleration and rotational velocity sensors were used simultaneously to obtain the centripetal acceleration and the angular velocity and verify the elementary relationship between those variables. In addition, by means of linear regressions, the rotation radius can be easily obtained.

The physical pendulum, one of the most paradigmatical mechanical system, was also studied using simultaneously the accelerometer and gyroscope [4-6]. In this setup, a smartphone affixed to a bicycle wheel was subject to both rotational and oscillatory motion. Thanks to the smartphone's capabilities two acceleration components and the angular velocity can be readily obtained. Several activities can be proposed from this experiment. A secondary or high-school lab can be centered in the rotational kinectic energy and the characteristics of the oscillatory motion [4]. In intermediate contexts interesting questions about the equivalence principle can be raised [5], while in advances laboratories, in this relatively simple system with one degree of freedom, a generalized coordinate and the conjugate momentum can be determined, enabling the representation of trajectories in the phase space [6]. This latter, rather abstract concept is rendered more tangible.

The accelerometer can also be employed in conjunction with the pressure sensor to obtain (and corroborate the coherence of) the vertical component of the velocity of elevators, pedestrians climbing stairs, and flying unmanned aerial vehicles [7]. This is an example of outreach activity that can be performed with student or a general audience. It is shown in this reference that the pressure sensor outperforms the accelerometer and GPS in several contexts.

In another experiment, the pressure sensor and the GPS were used in synchrony to find the relationship between atmospheric pressure and altitude [8] and gain insight into the characteristics of the inner atmosphere. In this case the setup is a bit more complex because the smartphone is mounted on a quadcopter. Both the altitude and the pressure are obtained using the built-in sensors. The results can be compared with reference values and other simple approximations as the isothermal and constant density atmospheres.

Optics also offers the possibility of doing smartphone experiments. Recently, the advantage of the capabilities of a smartphone to verify the Malus' law was proposed [9]. In this case, the intensity of polarized light from a computer monitor is measured by means of the luxometer (or ambient light sensor) with a small polarizer attached to it while the angle between the polarization and the polarizer is measured using of the orientation sensor. The simultaneous use of these two sensors allows us to simplify the experimental setup and complete a set of measures in just a few minutes.

In a different mixture of sensors the magnetometer and accelerometer were also used in synchrony [10] to obtain the spatial dependence of magnetic fields in simple configurations. In the simplest version, a smarphone is mounted on a track whose direction coincides with the axis of a coil. The smartphone is gently accelerated and both the distance (integrated numerically from the acceleration values) and the magnetic field are simultaneously obtained.

3 Conclusion

As appreciated in the discussed examples the synchronous use of several smartphone sensors opens the possibility of numerous physics experiments. Most modern smartphones present around a dozen of sensors. From simple arithmetic, using only two sensors, there are about half a hundred of combinations of sensors. So, let our imagination soar and devise new experiments.

References

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