한국컴퓨터정보학회 하계학술대회 논문집 제19권 제2호 (2011. 6)

추락하는 자동차가 수평으로 날아간 거리

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Horizontal Distance Traveled by a Falling Car

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● 요 약 ●

Telematics services include automatic location tracking for emergency rescue, which is available for use in case of a car accident due to falling off roadways. This paper presents a simulation study on how far a car will fall before it hits the ground, if dropped off the roadway due to an accident or a natural disaster. The greatest distance the falling car can travel is presented in this paper, on the assumption that air resistance as well as the direction and size of the acceleration due to gravity is negligible.

키워드: Telematics Service, Simulation Study, Accident, Natural Disaster

I. Introduction

In this paper we measured the distance a car traveled as a function of velocity car when sinkholes were formed on some parts of the roadway that was washed away by the flood. In other words, depressions with a depth of two, three, and four meters were formed on the roadway, due to the massive floods that swept away some parts of the road, or a man-made disaster.The car was running at a velocity of 40m/s, 50m/s, 60m/s, 70m/s, and 80m/s when it went over the edge of the depressions on the roadway. What concerns us here is how far this car will fall off the edge of the washed-away roadway before it hits the ground. This means the horizontal distance the car will travel after it passes the edge of the roadway. As long as you know how long the car will be in the air, you can find out the horizontal distance with ease.

One study was conducted on the method whereby the exact value of the field equation, which represents a magnetic monopole in a state of uniformly accelerated motion, is found by applying equiangular transformation to the well-known value of the magnetic monopole [1]. Another study was conducted to develop materials for learning the key ideas of calculus; this study involved analysis of the changes in the graph in which the state of uniformly accelerated motion is modeled not only through reflecting the suggestions for teaching and learning calculus, but also through a combination of physics and mathematics [2]. 3D game programming and mathematics for computer graphics applications deal with projectile motion that is the fundamentals of linear physics [3]. Web-based video digitizing systems are also used to do research into projectile motion [4].

II. Constant Acceleration

The average acceleration at the time interval Δt is as follows:

$$\bar{a} = \frac{\Delta v}{\Delta t} \qquad \text{Expression 1}$$

Where Δv refers to the change of velocity over time, and $\bar{a}$ means the average acceleration. The instantaneous velocity, the amount of velocity that can vary with time at each point in time, refers to the limit of the ratio between the displacements Δx and Δt as the time interval Δt approaches zero(0).

$$v = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t}$$ Expression 2

Thus, the instant velocity a is as in the following:

$$a = \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t} = \frac{dv}{dt}$$ Expression 3

Uniformly accelerated motion means motion with constant acceleration. If an object starts to move at a velocity of v0 at an initial point in time t=0, and moves at a velocity of v at a later point in time t, the change in velocity divided by the time interval between t=0 and t is the average acceleration $\bar{a}$. Since acceleration is constant, however, the average value of acceleration is the same as the instantaneous value.

$$a = \bar{a} = \frac{\Delta v}{\Delta t} = \frac{v - v_0}{t - 0}$$ Expression 4

Expression 3 can be restated like this:

$$v = v_0 + at$$ Equation 5

The change in velocity, in other words, is the product of the initial velocity and time.

As described above, in case of constant acceleration, we find the velocity as a function of time. Now, let's figure out displacements over time. Unless the velocity is constant, there is no way of multiplying the velocity by time. In case of constant acceleration, however, the velocity increases at a constant rate, and the average velocity at a certain time interval becomes the average velocity between the initial point in time and the end point in time of that time interval. The following is the average velocity between the initial point in time t=0 and the end point in time when the velocity is v.

$$\bar{v} = \frac{1}{2}(v_0 + v)$$ Expression 6

The average velocity can be found by dividing the displacement by the time interval. If t=0 and an object is at a certain location x0, the average velocity between two points in time 0 and t is as follows:

$$\bar{v} = \frac{\Delta x}{\Delta t} = \frac{x - x_0}{t - 0}$$ Expression 7

In Expression 7, x refers to the location of the object at the point in time t. If $\bar{v}$ in Expression 7 is the same as $\bar{v}$ in Expression 6, the location of the object is as in the following.

$$x = x_0 + \bar{v}t = x_0 + \frac{1}{2}(v_0 + v)t$$ Expression 8

The instantaneous velocity v is already derived as in Expression 5. What follows is a combination of Expression 5 and Equation 8 that results in the location as a function of time.

$$x = x_0 + v_0 t + \frac{1}{2}at^2$$ Expression 9

Ⅲ. Gravitational acceleration

What we've learned is that the only force acting upon an object in free fall is gravity. Such an object experiences a downward acceleration of 9.8 m/s2, the value of acceleration due to gravity on earth. This acceleration applies to the object upon which the only force acting is gravity. The same acceleration 9.8 m/s2 applies to all objects near the surface of the earth, regardless of their mass or geometrical properties. The symbol g stands for gravitational acceleration.

Ⅳ. Projectile motion

To describe projectile motion, you need to have the coordinate system with the x axis horizontal to the initial velocity of a projectile, and the y axis vertical with the positive direction going upwards. If you have done so, the direction toward the z axis has no components of velocity and/or acceleration; this allows for two dimensional motion in the xy plane. For the gravitational acceleration, ax is 0 while ay is -g. Therefore, Expression 5 and Equation 9 can be expressed as follows:

$$v_x = v_{x0}$$
$$v_y = v_{y0} - gt$$
$$x = x_0 + v_{x0}t$$
$$y = y_0 + v_{y0}t - \frac{1}{2}gt^2$$

As described above, g has a negative sign of acceleration pointing downwards.

Ⅴ. Experimental Resuts

Analyzing vertical motion allows you to figure out the above-mentioned time. The reason for vyo=0 is that the car in a horizontal motion went off the road. If the origin of the coordinate system is placed under the bottom of the washed-out road, y0 becomes 2m, 3m, and 4m, respectively. First off, if y=0, t is obtained as follows:

$$t = \sqrt{\frac{2y_0}{g}}$$

The equation above shows how long it took the car to fall straight down to the bottom of the washed-out road from a height of 2m, 3m, and 4m. The following is the distance the car traveled horizontally during that time at a velocity of 40m/s, 50m/s, 60m/s, 70m/s, and 80m/s.

$$x = vx0t$$

Table 1 shows how far the car, while running at a velocity of 40m/s, 50m/s, 60m/s, 70m/s, and 80m/s, will be thrown into the air from the end of the washed-out roadway with depressions 2m, 3m, and 4m deep before it falls down to the ground. t refers to the time it took for the car to fall free, and x to the distance it traveled horizontally.

$H_i^r(k)$, $H_i^g(k)$ and $H_i^b(k)$ represent the number(N) of the bin(k) in the ith frame(fi)for the respective color space (r,g,b).While the color histogram method is highly sensitive not only to the motion of a camera and an object, but also to light and shade, resulting in a loss of lots of data, we have found out that this method is a good trade-off between accuracy and speed.

Figure 3 is a graphical representation of it. The footage in Figure 4 shows those trapped inside the wrecked car being rescued after the car went off the roadway and fell down to the ground.

Table 1. Distance of Horizontal Traveling

depth	velocity	t	horizontal distance
2	50	0.638877	31.94382825
2	60	0.638877	38.3325939
2	70	0.638877	44.72135955
2	80	0.638877	51.1101252
2	90	0.638877	57.49889085
3	50	0.782461	39.12303982
3	60	0.782461	46.94764779
3	70	0.782461	54.77225575
3	80	0.782461	62.59686371
3	90	0.782461	70.42147168
4	50	0.903508	45.17539515
4	60	0.903508	54.21047417
4	70	0.903508	63.2455532
4	80	0.903508	72.28063223
4	90	0.903508	81.31571126

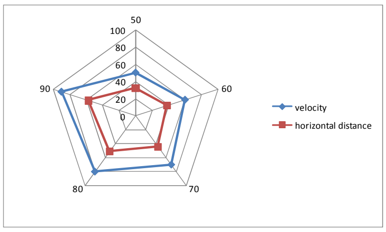

Fig. 3. Graphical Representation

Fig. 4. Car That Felling Down

Ⅵ. Conslusion

This paper provided a detailed description of how far the car would be thrown from the end of the depressions on the roadway until it fell down to the ground. We assumed that the car accident was due to either a natural disaster like flood or a man-made disaster like falling off the overpass. On the assumption that any changes in the direction and size of gravitational acceleration as well as air resistance are negligible, we showed the maximum fee-fall time, velocity and horizontal distance the car traveled, through a graphical representation of our simulation results.

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