Killer on the Run

Objectives:

Students will be able to:

1. enter data in a table and display the data graphically on a scatter plot
2. compute and interpret the linear correlation coefficient for the data
3. determine whether a linear relation exists between two variables
4. find the least-squares regression line and use the line to make predictions
5. compute and interpret the coefficient of determination
6. perform residual analysis on a regression model
7. determine if there is a relationship between the length of a person's stride and his or her height
8. determine if there is a relationship between the size of a person's shoes and his or her height

Materials

1. TI-83/TI-84 Plus Family
2. for station 1: metric tape measure or meter stick
3. for station 2: metric ruler
4. for station 3: metric tape measure or meter stick, straight walkway at least 10 m long, chalk or tape

Introduction

The body of a famous pop music producer Jonathan Wallace was found in his bathtub. It is believed that the intruder surprised the victim and drowned him. The only clue at the crime scene was a set of muddy footprints leading from a nearby window to the bathroom and back again. The footprints were smeared, so their exact size could not be determined. The soles of the shoes had no pattern. It will be difficult to match the footprints to any particular pair of shoes.

Three suspects were questioned immediately following the murder:

- Penelope Paige, pop star: 5 feet 4 inches tall, green eyes, blond hair
  Possible motive: she is suing Wallace over the failure of her last album
- Rex Chapman, rock guitarist: 5 feet 8 inches tall, brown eyes, brown hair
  Possible motive: he accused Wallace of stealing profits from his hit single "Walk It Off"
- Dirty Dawg, rapper: 6 feet, brown eyes, black hair
  Possible motive: he wants out of a record contract with Wallace.

Footprints were found, presumed to have been left by the murderer. The prints are 25 – 30 cm. long. Heel-to-heel stride length is 64-65 cm.

Procedure

Part I: Collect the Data

1. Set up three stations with two people at each, one person to collect data and one person to record data.
    a. At station 1, use the tape measure or meter stick to measure each person's height without shoes to the nearest half centimeter. Record the data.
    b. At station 2, have each person remove his or her right shoe. Turn the shoe over and use a ruler to measure the distance from the tip of the toe to the end of the heel. Record the length of the person's shoe.
    c. At station 3, mark a starting line with chalk or tape. Have each person stand with the backs of his or her heels at the edge of the starting line. Starting at this point, each person should take 10 normal-length walking steps in a straight line. After the 10th step, the person should stop and bring his or her heels together. Mark the final position of the back of the person's heels, and measure the distance in centimeters between that mark and the edge of the starting line. Calculate the average stride length and record the data for each person in centimeters.

Part II: Analyze the Data

1. Suppose data collection produced the following sample data.

Student Name	Height (cm)	Shoe Length (cm)	Stride Length (cm)
Student 1	146.5	23.0	58.0
Student 2	158.5	25.5	70.5
Student 3	186.5	28.0	88.0
Student 4	176.5	23.0	82.0
Student 5	180.0	30.5	85.0
Student 6	161.0	25.5	64.5
Student 7	174.0	28.0	77.5
Student 8	189.0	28.5	89.0
Student 9	181.5	23.5	84.5
Student 10	184.0	30.0	86.5
Student 11	149.0	23.0	59.5
Student 12	152.5	24.0	68.0
Student 13	155.5	26.0	69.5
Student 14	173.5	24.5	81.0
Student 15	181.0	30.0	85.0

2. a. Create a scatter plot of height versus stride length. Does the scatter plot imply a linear relationship between the two variables?

b. Compute and interpret the linear correlation coefficient for the data. Does the linear correlation coefficient imply a linear relationship between the variables?

c. Find the least-squares regression line for the data.

d. Compute and interpret the coefficient of determination for the data.

e. Perform residual analysis on the regression model.

f. Using the relationship between height and stride length that you calculated, determine the approximate heights of people with the following stride lengths: a) 75.5 cm, b) 45.5 cm, and c) 50.0 cm

3. a. Create a scatter plot of height versus shoe length. Does the scatter plot imply a linear relationship between the two variables?

b. Compute and interpret the linear correlation coefficient for the data. Does the linear correlation coefficient imply a linear relationship between the variables?

c. Find the least-squares regression line for the data.

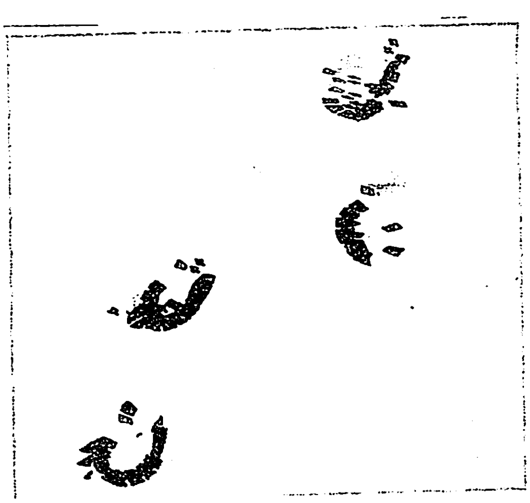
d. Compute and interpret the coefficient of determination for the data.

e. Perform residual analysis on the regression model.

f. Do you think it is possible to infer a person's height from his or her shoe size?

Part III: Solve the Case

Using the relationships that you calculated, determine which of the three suspects most likely left the footprints to and from Jonathan Wallace's bathroom. Show all your calculations.



Critical Values for Correlation Coefficient

n		*n*		*n*		*n*	
3	0.997	10	0.632	17	0.482	24	0.404
4	0.950	11	0.602	18	0.468	25	0.396
5	0.878	12	0.576	19	0.456	26	0.388
6	0.811	13	0.553	20	0.444	27	0.381
7	0.754	14	0.532	21	0.433	28	0.374
8	0.707	15	0.514	22	0.423	29	0.367
9	0.666	16	0.497	23	0.413	30	0.361

Blood Splatter at the Crime Scene

Objectives:

Students will be able to:

1. enter data in a table and display the data graphically on a scatter plot
2. explore fitting data to various curves such as linear, quadratic, logarithm, and power
3. use the coefficient of determination to determine which curve is a best fit to data
4. determine if there is a relationship between the height at which blood is dropped and the diameter of the corresponding blood splatter
5. Identify factors at the crime scene that can influence the relationship between height and diameter
6. Identify factors that can contribute to inaccuracies in data estimates

Materials

1. TI-83/TI-84 Plus Family
2. newspaper
3. white paper
4. droppers
5. simulated blood
6. calipers, or compass and metric ruler
7. meter stick

Introduction

Museum curator Jessica Barnes was found dead the day before the grand opening of the world famous traveling exhibit Shadows of Egypt. The victim had been strangled. A few drops of blood were found on the tile floor, but blood tests show that the blood is not the victim's. Investigators found traces of the same blood on the victim's knuckles. Investigators are suggesting that she fought her attacker, giving him or her a bloody nose or lip, and that the blood dripped onto the floor as the attacker fled the scene. The small volume of blood suggests the wound was minor and would have healed by the time the suspects were apprehended. We may be able to narrow down the height of the killer from the blood splatter evidence. The suspect list includes the following people:

- Abraham Stein- photo archivist: 6 feet 2 inch, brown eyes, brown hair, knew Barnes was trying to cut funding for his vintage photo department
- Ellie Walsh- museum curator: 5 feet 3 inch, green eyes, brown hair, was a candidate for the head curator position six months ago, along with Barnes
- Keith Hartman- administrative assistant: 5 feet 8 inches, blue eyes, blond hair, was recently fired by Barnes

Procedure

Part I: Collect the Data

1. Create blood splatters from known heights and compare them with unknown samples.
   a. Spread newspaper on the ground. Place a piece of white paper on the newspaper.
   b. Fill a dropper with simulated blood. Drop a single drop onto the white paper from a height of 10 cm.
   c. Measure the diameter of the splatter in millimeters, using calipers or a compass. (If the splatter has a ragged edge, measure only the diameter of the main blood drop). Record the data. Repeat two more times from height of 10 cm.
   d. Calculate the average diameter of the splatter that fell from 10 cm and record the data.
   e. Repeat the process from heights of 20, 30, 40 50, 60 80, 100 120, 140, 160, 180, and 200 cm.

Part II: Analyze the Data

1. Suppose data collection produced the following sample data (using Pepto-Bismol)

Height (cm)	Diameter of Drop 1 (mm)	Diameter of Drop 2 (mm)	Diameter of Drop 3 (mm)	Average Diameter of Drops (mm)
10	7	7	7	7
20	10	10	12	10.7
30	10	13	12	11.7
40	14	12	13	13
50	12	13	13	12.7
60	14	14	14	14
80	15	16	15	15.3
100	17	17	17	17
120	18	18	18	18
140	18	18	18	18
160	18	18	18	18
180	20	20	20	20
200	20	20	20	20
Crime Scene	11	12	11	11.3

2. a. Create a scatter plot of drop height versus the average splatter diameter. Does the scatter plot imply a linear relationship between the two variables?

   b. Fit a straight line to the data and determine the coefficient of determination.

c. Fit a natural logarithm to the data and determine the coefficient of determination.

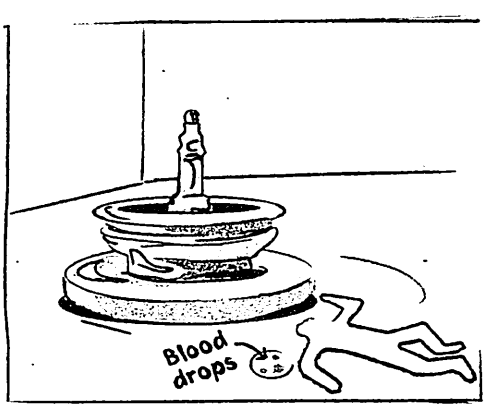
d. Fit a quadratic curve to the data and determine the coefficient of determination.

e. Fit a power curve to the data and determine the coefficient of determination.

f. Determine which curve best fits the data.

Part III: Solve the Case

1. Estimate the height from which the blood at the crime scene fell by comparing it to your known data.
2. Which of the suspects could have created the blood splatters at the crime scene?
3. How accurate do you think your height estimate is? What factors can contribute to inaccuracy in your estimate? How can you reduce the errors from these factors?
4. Forensic scientists often do tests to determine the relationship between height and splatter diameter for the different cases they are involved in. What factors can cause the relationship between height and splatter diameter to differ from crime scene to crime scene?



Hit and Run Accident

Objectives:

Students will be able to:

1. Describe how distance traveled, velocity, and acceleration are related to one another
2. Describe how the appearance of an acceleration, velocity, or distance versus time graph can be used to predict the appearance of the other graphs
3. Simulate the use of an event data recorder (EDR) in order to show how the evidence gathered by this device can be used for legal purposes
4. Describe how accident scenes can be recreated through an analysis of the data that are gathered by an EDR.

Materials

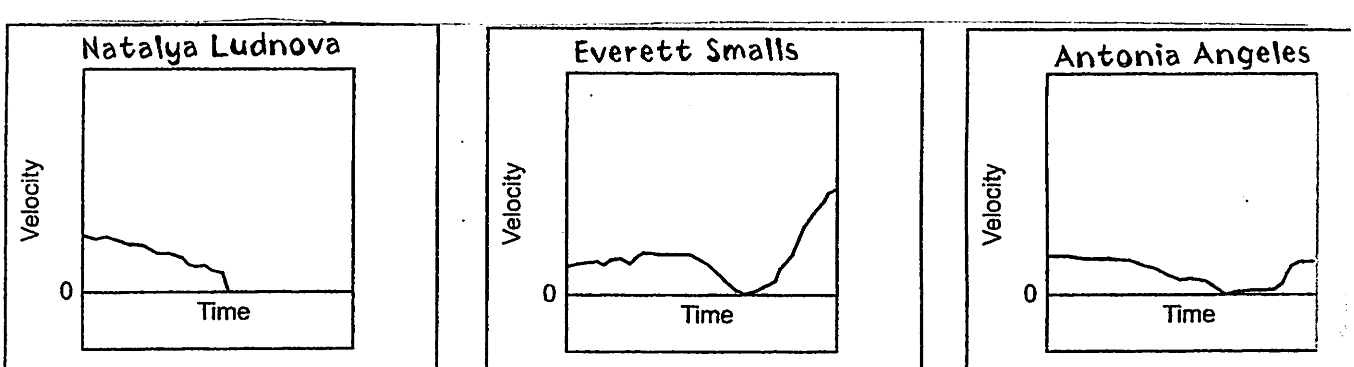
1. TI-83/TI-84 Plus Family
2. Vernier EasyData application
3. Calculator-Based Ranger 2
4. toy car, at least 5 cm tall

Introduction

Rania Sallum, 58, was struct by a large, dark-colored SUV Wednesday around 7:20 a.m. Sallum could not see the driver or read the license plate, but she knows that she was struck by the front right bumper of the vehicle, which then slowed almost to a stop before speeding off. She estimates that the incident occurred between 7:15 and 7:25 a.m. A hit-and-run bulletin and vehicle description went out to all officers. Three police teams spotted vehicles with front right bumper damage and recorded the following information from their drivers:

- Natalya Ludnova- 25- pulled over for speeding when the officer noticed bumper damage-claimed that damage was due to hitting the curb while parking
- Everett Smalls- 38- brought in for blocking a fire lane-claimed that bumper was damaged in a stop-and-go rush hour fender bender
- Antonia Angeles-53- pulled over for speeding when the officer noticed bumper damage-claimed a neighbor backed into her car as she drove past his driveway

EDR data downloaded from each car for the 10 seconds before and after the bumper collision show that each occurred between 7 and 8 a.m. Wednesday.

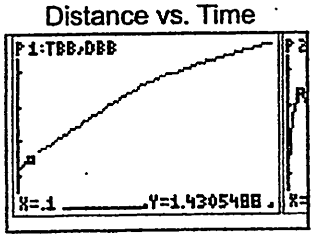


Procedure

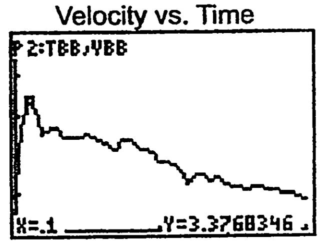
Part I: Collect the Data

1. Connect the CBR 2 to the calculator with the USB cable. EasyData will open immediately, and the CBR 2 will begin collecting distance data.
2. Place the CBR 2 and the car on the floor. The CBR 2 should be facing the car, and they should be about 30 cm apart.
3. Observe the calculator display to make sure that the CBR 2 is picking up the position of the car. It should show a distance of about .3m.
4. Perform a test run with the car. Have one team member push the car and release it. Have another team member check the readings on the calculator screen. You do not need to record the motion at this point. Just be sure that the CBR 2 is measuring the increasing distance to the car as it moves away.
5. Now begin the experiment. Set the parameters to have the calculator record one sample every .05 seconds for 3 seconds and record 60 samples.
6. After the data is collected, a distance versus time graph will automatically plot on the screen. Examine the velocity versus time graph as well. These graphs should be relatively smooth, indicating you picked up the motion of the vehicle and not a lot of extraneous noise.

Distance vs. Time



Velocity vs. Time



If the graphs are not relatively smooth, repeat the experiment again.

Part II: Analyze the Data

1. Look at the velocity versus time graph plotted by your calculator. At what time did the car begin to move?
2. What was the maximum velocity of the car?
3. At what time did the car reach its maximum velocity?
4. Look at the distance versus time graph plotted by your calculator. Does the time at which the car's distance from the CBR 2 increased match the time in question 1?
5. How far did the car move before it reached its maximum velocity?
6. EDRs in vehicles record information on velocity and acceleration for moving vehicles. The data recorded by EDRs help reconstruct the events of an accident. For example, data from the EDR can show when a car's brakes were applied, if at all. Suppose a vehicle were traveling at a constant speed, using cruise control, when suddenly the brakes were applied until the vehicle stopped. Sketch a velocity versus time graph for this situation. Label the

point at which the brakes were applied and the point at which the vehicle came to a complete stop.

Part III: Solve the Case

Do the EDR data taken from the suspects support their stories? Do the EDR graphs suggest that any of these suspects is the culprit in the hit and run? Explain your answers.

References

1. Forensics: Connecting Science Investigations with TI Data Collection Activities by Jacklyn Bonneau – Texas Instruments – 2005
2. Statistics: Informed Decisions Using Data , 3rd edition, by Michael Sullivan, III, Pearson, 2009.

Other cases in the book:

- Using ground-penetrating radar to locate buried objects
- Matching musical tones through waveform analysis
- Flipping coins: density as a characteristic property
- Using colorimetry to identify an unknown ink
- Using momentum to determine intent
- Identifying an unknown chemical
- Using soil characteristics to link suspects to a crime scene
- Using colorimetry to determine concentration of a poison
- Using evaporation rate to identify an unknown liquid
- Using skid marks to determine vehicle speed
- Using Newton's law of cooling to determine time of death