Medical Data Analysis in Excel
Part I

CIS 1902103: Computer Skills for Medical Students

By:
Dr. Raja Alomari, Tamara Almarabeh and Lama Rajab

Dept of Computer Information Systems
King Abdullah II School for Information Technology
The University Of Jordan

Central Tendency Measurements

Central Tendency: mean, median, and mode

- The **mean** is the average of data values

$$mean = \frac{\sum x_n}{n} = \frac{x_1 + x_2 + ... + x_n}{n}$$

- **Example:**

The mean for 5 values: 4,36,45,50,75 is

$$\frac{4+36+45+50+75}{5} = \frac{210}{5} = 42$$

- **In Excel:**

= average(range of cells)

Central Tendency Measurements

- The **median** is the middle value of the data after sorting.
  - If n **is odd** then Median $= x\left(\frac{n+1}{2}\right)$
  - If n **is even** then Median $= \frac{x\left(\frac{n}{2}\right) + x\left(\frac{n}{2}+1\right)}{2}$
- **Example :**

The median for 4, 9, 6, 12, 16 = 9

The median for 4, 9, 6, 12, 19, 16 = 10.5

- **In Excel :**

=median(range of cells)

Central Tendency Measurements

- The **mode** is the most frequently occurring
- **Example:**

The mode for 2, 2, 9, 6, 12, 8 = 2

The mode for 2, 2, 4, 6, 7, 8, 4 = 2 and 4

The mode for 2, 6, 9, 16, 12, 8, -2, 0.4 = Not available (no mode)

- **In Excel:**

=mode (range of cells)

Department of Computer Information Systems
King Abdullah II School for Information Technology
The University of Jordan

Dispersion Measurements

Dispersion: Range, variance, and standard deviation

- **Range** : Max – Min
- **Example:**

The range for *2, 6, 8, 9, 12 = 12-2=10*

- **In Excel:**

=max(range of cells) - min(range of cells)

Dispersion Measurements

- The **variance** is given by: $\text{variance} = \frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2$
- **Example:**

The variance for 5, 6, 2, 8, 9 = 7.5

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{5} x_i = \frac{2+5+6+8+9}{5} = 6$$

x	2	5	6	8	9	Total sum
$(x_i - \bar{x})$	-4	-1	0	2	3	0 = sum of residuals
$(x_i - \bar{x})^2$	16	1	0	4	9	30

$$\frac{30}{4} = 7.5$$

- **In Excel:**

=var(range of cells)

Department of Computer Information Systems
King Abdullah II School for Information Technology
The University of Jordan

Dispersion Measurements

- The **Standard deviation** is given by:
- standard deviation $= \sqrt{\frac{\sum(x_i - \bar{x})^2}{n-1}}$
- **Example**:

The standard deviation for 5, 6, 2, 8, 9 = $\sqrt{7.5} = 2.73861$

- **In Excel:**
  - =stdev(range of cells)

The Relationship between variables

Correlation and Covariance

- Covariance and correlation describe how two variables are related.
  - Variables are positively related if they move in the same direction
  - Variables are inversely related if they move in opposite directions.

Both **covariance** and **correlation** indicate whether variables are positively or inversely related.

Correlation also tells you the degree to which the variables tend to move together.

Department of Computer Information Systems
King Abdullah II School for Information Technology
The University of Jordan

Covariance

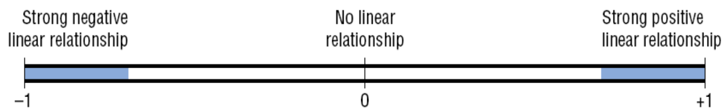
- Covariance determines:
  - ➢ How two variables are related.
  - ➢ Whether variables are positively or inversely related.

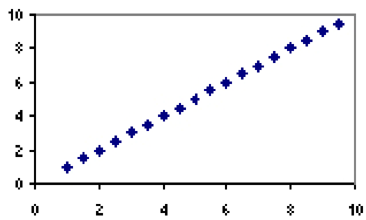
    A positive covariance means the variables are positively related, while a negative covariance means the variables are inversely related.
- For example: The covariance between market returns and economic growth is 1.53. Since the covariance is positive, the variables are positively related—they move together in the same direction

Correlation

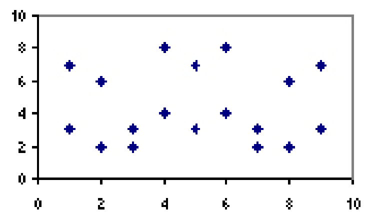
- Correlation determines:
  - ➢ How two variables are related.
  - ➢ Whether variables are positively or inversely related.
  - ➢ The degree to which the variables tend to move together.
- Correlation standardizes the measure of interdependence between two variables and, consequently, tells you how closely the two variables move.

- The correlation measurement, called a correlation coefficient, will always take on a value between 1 and – 1:
- *If the correlation coefficient is one*, the variables have a perfect positive correlation. This means that if one variable moves a given amount, the second moves proportionally in the same direction.
- *If correlation coefficient is zero*, no relationship exists between the variables. If one variable moves, you can make no predictions about the movement of the other variable; they are uncorrelated.
- *If correlation coefficient is –1*, the variables are perfectly negatively correlated (or inversely correlated) and move in opposition to each other. If one variable increases, the other variable decreases proportionally.

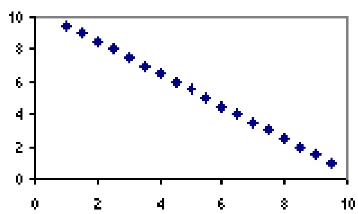




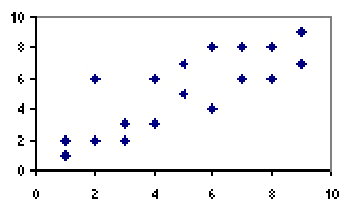
Correlation = 1
Maximum Positive Correlation



Correlation = 0
Zero Correlation



Correlation = -1
Maximum Negative Correlation



Correlation = 0.8
Strong Positive Correlation

For example:

- The correlation between market returns and economic growth is 0.66.

A correlation coefficient of .66 tells you two important things:

- Because the correlation coefficient is a positive number, market returns and economic growth are positively related.
- Because .66 is relatively far from indicating no correlation, the strength of the correlation be is strong.

Correlation and Covariance in Excel

- To find the correlation , you can use the **Correl** function

=Correl (range of x-variable, range of y-variable)

- To find the covariance , you can use the **Covar** function

=Covar(range of x-variable, range of y-variable)

Test Measurements

True Positive (TP)

- Number of cases where the patient tests positive on a disease when he/she actually has the disease.

i.e.,

- Patient has the disease.
- The test gives positive result for the disease (test says patients have the disease).

Example :

If the patient "has an allergy " and the test is positive → True positive.

Department of Computer Information Systems
King Abdullah II School for Information Technology
The University of Jordan

False Positive (FP)

- Number of cases where the patient tests positive on a disease when he/she actually does not have the disease.

i.e.,

- Patient does not have the disease.
- The test gives positive result for the disease (test says patients have the disease).

Example :

If the patient "doesn't have an allergy " and the test says "yes".

17

True Negative (TN)

- Number of cases where the patient tests negative on a disease when he/she actually does not have the disease.

i.e.,

- Patient does not have the disease.
- The test gives negative result for the disease (test says patients does not have the disease).

Example :

If the patient "doesn't have an allergy " and the test says "No".

18

False Negative (FN)

- Number of cases where the patient tests negative on a disease when he/she actually has the disease.

i.e.,

- Patient has the disease.
- The test gives negative result for the disease (test says patients does not have the disease).

Example :

If the patient "has an allergy " and the test says "No".

19

Medical Screening V.S. Testing

Medical Screening

- Relatively cheap diagnostic tools for large population to detect abnormalities.
- If positive, leads to more testing.
- False positives are acceptable. False negatives are not.

Types :

-- **Universal screening** involves screening of all individuals in a certain category (for example, all children of a certain age).

-- **Case finding** involves screening a smaller group of people based on the presence of risk factors (for example, because a family member has been diagnosed with a hereditary disease).

Medical Testing

- Relatively more expensive diagnostic tools.
- Testing tend to prove the elimination of both FP and FN.
- A False Negatives are dangerous at the testing stage.
- False Positives are dangerous if this test of the final stage of testing to determine treatment.

20

Medical Screening: Example

Example :

Mammography: is utilizing a low-energy X-ray radiographs for Breast cancer screening.

The ideal Mammography test should:

1. Cheap
2. Zero False Negatives
3. Relatively small False positives.

Ground Truth & Gold Standard

"Ground truth:" The objective data of a test. e.g., patient x has liver cancer.
In practice, the Ground truth is hard to get in medical domain due to the inter-observer variability.

Department of Computer Information Systems
King Abdullah II School for Information Technology
The University of Jordan

Ground Truth & Gold Standard

"Gold Standard:" is a method or procedure that is identified as the best available test for diagnosing a particular disease under reasonable conditions.
For example : in brain tumor diagnosis , the biopsy is an accurate test for this disease. But it can't be applied so MRI is the gold standard for brain tumor diagnosis, though it is not as good as biopsy.

Diagnostic Accuracy (effectiveness)

- The proportion of the success rate of a given test.

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN}$$

Department of Computer Information Systems
King Abdullah II School for Information Technology
The University of Jordan

Statistical measures of the Test performance :

1. Sensitivity and Specificity :

Sensitivity and Specificity Address the question :

How Often is the Test Right ?

- Performed in variable population including normal and abnormal subjects inorder to validate a given medical test or experiment.

Define: Sensitivity

- A measure of the test ability to measure positive cases.

$$Sensitivity = \frac{TP}{TP + FN}$$

The percentage of sick people who are correctly identified as having the condition .

Among People with Disease , How often is the test right ?

Department of Computer Information Systems
King Abdullah II School for Information Technology
The University of Jordan

Discuss: Sensitivity

- A test with 100% sensitivity correctly identifies all patients with the disease.
- A test with 80% sensitivity detects 80% of patients with the disease (true positives) but 20% with the disease go undetected (false negatives).
- A high sensitivity is clearly important where the test is used to identify a serious but treatable disease (e.g. cervical cancer).

27

Define: Specificity

- A measure of the test ability to measure negative cases.

$$Specificity = \frac{TN}{TN + FP}$$

Among People are normal, How often is the test right ?

28

Discuss: Specificity

- A test with 100% specificity correctly identifies all normal patients.
- A test with 80% specificity correctly reports 80% of normal patients as test negative (true negatives) but 20% normal patients are incorrectly identified as abnormal (false positives).

Example 1 : Sensitivity

Test	Gold Standard: Influenza	Gold Standard: No Influenza
Positive	TP = 80	FP= 5
Negative	FN = 20	TN = 95

Sensitivity = 80 / (80 + 20)
= 0.80 (or 80%)

Department of Computer Information Systems
King Abdullah II School for Information Technology
The University of Jordan

Example 1 : Specificity

	Gold Standard: Influenza	Gold Standard: No Influenza
Test Positive	TP = 80	FP= 5
Negative	FN = 20	TN = 95

Specificity = 95/ (95 + 5)
= 0.95 (or 95%)

Positive Predictive Value (PPV)

- The proportion of positive test results that are true positives.
- Also known as Precision Rate

$$PPV = \frac{TP}{TP + FP}$$

- PPV of a test answers the question:

"How likely is it that this patient has the disease given that the test result is positive?"

Department of Computer Information Systems
King Abdullah II School for Information Technology
The University of Jordan

Negative Predictive Value (NPV)

- The proportion of negative test results that are true negatives.

$$NPV = \frac{TN}{TN + FN}$$

- NPV of a test answers the question:

  'How likely is it that this patient is normal (does not have the disease) given that the test result is negative?'

33

Discuss: PPV v.s. NPV

- PPV:
  - High value for a test indicates that when a test gives a positive outcome, it is more likely correct.
  - Low value for a test indicates that when a test gives a positive outcome, it is less likely correct.
- NPV

  High value for a test indicates that when a test gives a negative outcome, it is more likely correct.

  Low value for a test indicates that when a test gives a negative outcome, it is less likely correct.

34

Summary: Test Measurements

The Truth

Test Score:	Has the disease	Does not have the disease	
Positive	True Positives (TP) a	False Positives (FP) b	**PPV =** $\frac{TP}{TP + FP}$
Negative	c False Negatives (FN)	d True Negatives (TN)	**NPV =** $\frac{TN}{TN + FN}$

Sensitivity

$$\frac{TP}{TP + FN}$$

Or, $$\frac{a}{a + c}$$

Specificity

$$\frac{TN}{TN + FP}$$

$$\frac{d}{d + b}$$

35

Example 2 : Sensitivity & Specificity

2 x 2 table for Diagnostic Test Performance

	Disease	No Disease
Positive Test	90	200
Negative Test	10	800

What is the value of Sensitivity ?

What is the value of Specificity ?

36

Example 2 : Sensitivity & Specificity

2 x 2 table for Diagnostic Test Performance

	Disease	No Disease
Positive Test	True Positive	
Negative Test		True Negative

Correctly Classified Diagonal

37

Example 2 : Sensitivity & Specificity

2 x 2 table for Diagnostic Test Performance

	Disease	No Disease
Positive Test	True Positive	False Positive
Negative Test	False Negative	True Negative

Incorrectly classified Diagonal

38

Department of Computer Information Systems
King Abdullah II School for Information Technology
The University of Jordan

Example 2 : Sensitivity & Specificity

2 x 2 table for Diagnostic Test Performance

	Disease	No Disease
Positive Test	90	200
Negative Test	10	800

Sensitivity = 90/ (90 + 10) = 90%

Specificity = 800/ (200 + 800) = 80%

39

Example 2 : Sensitivity & Specificity

	Disease	No Disease
Positive Test	90	200
Negative Test	10	800

PPV = 90/ (290) = 0.31

NPV = 800/ (10 + 800) = 0.987

40

Definition: Inter-rater reliability

- Also Known as inter-rater agreement, concordance, inter-observer agreement (-reliability).
- A Measure of the degree of agreement (homogeneity) between judges (raters, observers) for rating a given task.
- E.g., Diagnosis of a disease may vary among several clinicians.

Measures: Inter-rater reliability

- Joint-probability of agreement
- Kappa statistics:
  - Cohen's kappa
  - Fleiss' kappa
- Correlation coefficients
- Intra-class correlation coefficient
- Limits of agreement

Department of Computer Information Systems
King Abdullah II School for Information Technology
The University of Jordan

Kappa Statistics

- Kappa is a statistical measure of agreement in ratings between two raters.
- For example, if two doctors evaluate a patient as either "sick" or "healthy" then kappa measures the extent of their agreement.

Cohen's Kappa

- It is a measurements to formulate agreement between the coders.

$$k = \frac{\Pr(a) - \Pr(e)}{1 - \Pr(e)}$$

Pr(a) : Observed agreement among coders .

$$\Pr(a) = \frac{(TP+TN)}{TP+TN+FP+FN}$$

Pr(e) : is the probability of random agreement.

Pr(e)=Pr(yes coder1) * pr(yes coder 2) + pr(no coder1)* pr(no coder 2).

Kappa Statistics Interpretation

Kappa Scale

Chance Agreement	Poor	Slight	Fair	Moderate	Substantial	Almost Perfect
< 0.0	0.0	.20	.40	.60	.80	1.0

Cohen's Kappa (Example)

Coder 2

		Yes	No
Coder 1	Yes	20	5
	No	10	15

Pr(a) = (20+15)/50 = 0.70

Pr(e) [Probability of Random Agreement]:

Coder 1 : said "YES" to 25 and "No" to 25 . Thus coder 1 says "YES" 50% of the time.

Coder 2 : said "YES" to 30 and "No" to 20 . Thus coder 2 said "yes" 60% of the time.

Department of Computer Information Systems
King Abdullah II School for Information Technology
The University of Jordan

Cohen's Kappa (Example)

Coder 2

Coder 1

20	5
10	15

Pr(a) = (20+15)/50 = 0.70

Pr(e) = 0.5 * 0.6 + 0.5 *0.4 = 0.3 + 0.2 = 0.5

Kappa= (0.7 – 0.5)/ (1-0.5) = 0.4 (Cohen's Kappa)

Department of Computer Information Systems
King Abdullah II School for Information Technology
The University of Jordan