Empirical Methods (CS 5453)
Homework 2 Solutions

May 21, 2011

Question 1

1. (10pts) Suppose that we are performing a robot navigation experiment in a busy building. The foot traffic level is a potential factor that could influence our performance metric (people could interfere with the robot's ability to navigate from one location to another). Should we consider this factor as an *extraneous* or a *noise* variable? Explain in detail.

   You answer could go either way on this. However, I would argue that the level of foot traffic cannot be controlled to a fine degree. Hence, we would consider this as a noise variable.

   Nevertheless, it would be possible to measure (or even directly determine) the level of foot traffic at a given time (e.g., by counting the number of people passing through a corridor). (more below)

2. (10pts) What is the relationship between a hypothesis and *extraneous variables*?

   Extraneous variables are a formal means of articulating alternative hypotheses that could explain an observed effect.

3. (10pts) Suppose that we were to consider foot traffic as a noise variable. Explain the process of controlling it.

   A noise variable is "controlled" by taking multiple independent samples within a particular condition. Computing a mean or a median of the performance metric across these samples will (hopefully) wash out the effects of the experimental conditions.

4. (10pts) Suppose that we were to consider foot traffic as an extraneous variable. Explain the process of controlling it.

   As described above, if we can explicitly measure the foot traffic or even explicitly determine the foot traffic (by having a set of "actors"), then we can consider foot traffic as an extraneous variable. One could partition the trials into several discrete buckets: (for example) low, medium and high traffic levels. In an experiment comparing two navigation algorithms, we could then control (by "selection") this extraneous variable by ensuring that within each bucket, we have the same number of samples for the two algorithms.

5. (10pts) Suppose that in comparing the performance of navigation algorithms A and B, we find that we have a ceiling effect. What could we change about the experimental design to solve this problem?

   We could make the conditions of the tests harder.

6. (10pts) Define *censoring*. Why would we need to use censoring in this experiment? Can we design the experiment so as to always avoid the need for censoring?

   Censoring is the process of removing data from a sample after the fact. We may use censoring if we are unable to compute the measure of interest on some sample. We may also use censoring to remove samples that we believe to be outliers (although always with caution). Many experiments can yield samples that are not measurable: an algorithm may completely fail or may take too long to execute; a human subject could stop performing the requested task. Hence, not all experiments can be designed to avoid our need for censoring.

In this experiment, censoring could be necessary if the physical hardware failed in some way or if the robot/algorithm required too much time to complete the trial.

7. (10pts) Define *sampling bias.* Could a sampling bias exist in this experiment?

   A sampling bias *is a situation in which the process of taking samples itself is a factor that affects the outcome of an experiment. In this experiment, we might choose to censor a trial if too much time had gone by. This choice could affect one algorithm more than the other.*

Question 2

The matlab variables "dat1," "dat2," and "dat3" contain a set of 3-tuple discrete observations (each of the data sets is represented as a single matrix). Columns 1 and 2 are independent variables; column 3 is a dependent variable.

1. (20pts) For dat1, describe in detail (including appropriate statistical tests) the influences that the independent variables have on the dependent variable.

   We will use a chi-squared test that looks individually at A's and B's influence on C.

   A influence on C

   cont =

   23 144 30

   125 594 84

   val =

   4.7893

   expected =

   29.1560 145.3860 22.4580

   118.8440 592.6140 91.5420

   chi2 =

   1.2998 0.0132 2.5328

   0.3189 0.0032 0.6214

   p =

   0.0912

   prob =

   0.1168 0.7310 0.1523

   0.1557 0.7397 0.1046

   NO INFLUENCE

   ———————————————

B influence on C

cont =

34 336 47

102 265 21

12 137 46

val =

99.0409

expected =

61.7160 307.7460 47.5380

57.4240 286.3440 44.2320

28.8600 143.9100 22.2300

chi2 =

12.4470 2.5940 0.0061

34.6026 1.5910 12.2022

9.8496 0.3318 25.4167

p =

0

prob =

0.0815 0.8058 0.1127

0.2629 0.6830 0.0541

0.0615 0.7026 0.2359

INFLUENCE

2. (20pts) For dat2, describe in detail (including appropriate statistical tests) the influences that the independent variables have on the dependent variable.

   A influence on C

   cont =

   23 158 21

   147 596 55

val =

7.5632

expected =

34.3400 152.3080 15.3520

135.6600 601.6920 60.6480

chi2 =

3.7448 0.2127 2.0779

0.9479 0.0538 0.5260

p =

0.0228

prob =

0.1139 0.7822 0.1040

0.1842 0.7469 0.0689

INFLUENCE

———————————————

B influence on C

cont =

40 278 34

127 419 29

3 57 13

val =

40.5391

expected =

59.8400 265.4080 26.7520

97.7500 433.5500 43.7000

12.4100 55.0420 5.5480

chi2 =

6.5780 0.5974 1.9637

8.7526 0.4883 4.9449

7.1352 0.0697 10.0094

p =

3.3481e-08

prob =

0.1136 0.7898 0.0966

0.2209 0.7287 0.0504

0.0411 0.7808 0.1781

INFLUENCE

3. (20pts) For dat3, describe in detail (including appropriate statistical tests) the influences that the independent variables have on the dependent variable.

   A influence on C

   cont =

   30 171 20

   109 480 190

   val =

   25.8809

   expected =

   30.7190 143.8710 46.4100

   108.2810 507.1290 163.5900

   chi2 =

   0.0168 5.1156 15.0288

   0.0048 1.4513 4.2636

   p =

   2.3990e-06

   prob =

   0.1357 0.7738 0.0905

   0.1399 0.6162 0.2439

INFLUENCE

—————————————————

B influence on C

cont =

85 274 23

31 337 40

23 40 147

val =

427.5860

expected =

53.0980 248.6820 80.2200

56.7120 265.6080 85.6800

29.1900 136.7100 44.1000

chi2 =

19.1672 2.5776 40.8144

11.6573 19.1892 24.3541

1.3126 68.4136 240.1000

p =

0

prob =

0.2225 0.7173 0.0602

0.0760 0.8260 0.0980

0.1095 0.1905 0.7000

INFLUENCE

4. (20pts) Describe a reasonable approach for formally testing whether there is an interaction effect between the independent variables in their influence of of the dependent variable. (you will need to invent this procedure.)

Given two independent variables A and B, the question is whether there is an interaction effect on C. One way to get at this question is as follows: for each choice of value for B, construct a contingency table of A's influence on C. If the chi-squared test yields a difference, then we can safely say that there is an interaction effect (though we may want to also deal with the multiple comparisons problem).

5. (10pts) For dat1, is there an interaction effect between the two independent variables?

   B=0, A influence on C

   cont =

   5 71 12

   29 265 35

   16 46 6

   86 219 15

   2 27 12

   10 110 34

   val =

   1.3896

   expected =

   7.1751 70.9065 9.9185

   26.8249 265.0935 37.0815

   chi2 =

   0.6594 0.0001 0.4368

   0.1764 0.0000 0.1168

   p =

   0.4992

   prob =

   0.0568 0.8068 0.1364

   0.0881 0.8055 0.1064

   ———————————————

B=1, A influence on C

val =

2.0165

expected =

17.8763 46.4433 3.6804

84.1237 218.5567 17.3196

chi2 =

0.1969 0.0042 1.4619

0.0418 0.0009 0.3107

p =

0.3649

prob =

0.2353 0.6765 0.0882

0.2687 0.6844 0.0469

———————————————

B=2, A influence on C

val =

0.9902

expected =

2.5231 28.8051 9.6718

9.4769 108.1949 36.3282

chi2 =

0.1084 0.1131 0.5604

0.0289 0.0301 0.1492

p =

0.6095

prob =

0.0488 0.6585 0.2927

0.0649 0.7143 0.2208

ANSWER: NO INTERACTION EFFECT

————————————-

A affecting B's influence:

A=0, B influence on C

cont =

5 71 12

29 265 35

16 46 6

86 219 15

2 27 12

10 110 34

val =

21.0630

expected =

10.2741 64.3249 13.4010

7.9391 49.7056 10.3553

4.7868 29.9695 6.2437

chi2 =

2.7074 0.6927 0.1465

8.1846 0.2763 1.8318

1.6224 0.2942 5.3071

p =

3.0769e-04

prob =

0.0568 0.8068 0.1364

0.2353 0.6765 0.0882

0.0488 0.6585 0.2927

———————————————

A=1, B influence on C

val =

77.5239

expected =

51.2142 243.3699 34.4159

49.8132 236.7123 33.4745

23.9726 113.9178 16.1096

chi2 =

9.6354 1.9224 0.0099

26.2879 1.3253 10.1960

8.1440 0.1347 19.8681

p =

5.5511e-16

prob =

0.0881 0.8055 0.1064

0.2687 0.6844 0.0469

0.0649 0.7143 0.2208

ANSWER: THERE IS AN INTERACTION EFFECT

ANSWER from both analyses: YES THERE IS AN INTERACTION EFFECT

6. (10pts) For dat2, is there an interaction effect between the two independent variables?

   B=0, A influence on C

   cont =

   19 126 15

   21 152 19

   4 16 0

   123 403 29

0 16 6

3 41 7

val =

0.0939

expected =

18.1818 126.3636 15.4545

21.8182 151.6364 18.5455

chi2 =

0.0368 0.0010 0.0134

0.0307 0.0009 0.0111

p =

0.9541

prob =

0.1187 0.7875 0.0938

0.1094 0.7917 0.0990

———————————————

B=1, A influence on C

val =

1.2305

expected =

4.4174 14.5739 1.0087

122.5826 404.4261 27.9913

chi2 =

0.0394 0.1395 1.0087

0.0014 0.0050 0.0363

p =

0.5405

prob =

0.2000 0.8000 0

0.2216 0.7261 0.0523

——————————————

B=2, A influence on C

val =

2.9937

expected =

0.9041 17.1781 3.9178

2.0959 39.8219 9.0822

chi2 =

0.9041 0.0808 1.1066

0.3900 0.0349 0.4774

p =

0.2238

prob =

0 0.7273 0.2727

0.0588 0.8039 0.1373

ANSWER: NO INTERACTION EFFECT

————————————-

A's affect on B's influence:

A=0, B influence on C

cont =

19 126 15

21 152 19

4 16 0

123 403 29

0 16 6

3 41 7

val =

12.2076

expected =

18.2178 125.1485 16.6337

2.2772 15.6436 2.0792

2.5050 17.2079 2.2871

chi2 =

0.0336 0.0058 0.1604

1.3033 0.0081 2.0792

2.5050 0.0848 6.0274

p =

0.0159

prob =

0.1187 0.7875 0.0938

0.2000 0.8000 0

0 0.7273 0.2727

———————————————

A=1, B influence on C

val =

23.6706

expected =

35.3684 143.3985 13.2331

102.2368 414.5113 38.2519

9.3947 38.0902 3.5150

chi2 =

5.8372 0.5159 2.5132

4.2168 0.3197 2.2377

4.3527 0.2223 3.4551

p =

9.2981e-05

prob =

0.1094 0.7917 0.0990

0.2216 0.7261 0.0523

0.0588 0.8039 0.1373

ANSWER: THERE IS AN INTERACTION EFFECT

ANSWER from both analyses: YES THERE IS AN INTERACTION EFFECT

7. (10pts) For dat3, is there an interaction effect between the two independent variables?

   B=0, A influence on C

   cont =

   14 65 9

   71 209 14

   1 79 8

   30 258 32

   15 27 3

   8 13 144

   val =

   5.4997

   expected =

   19.5812 63.1204 5.2984

   65.4188 210.8796 17.7016

   chi2 =

   1.5908 0.0560 2.5860

   0.4762 0.0168 0.7740

   p =

   0.0639

prob =

0.1591 0.7386 0.1023

0.2415 0.7109 0.0476

———————————————

B=1, A influence on C

val =

6.9231

expected =

6.6863 72.6863 8.6275

24.3137 264.3137 31.3725

chi2 =

4.8358 0.5484 0.0456

1.3299 0.1508 0.0125

p =

0.0314

prob =

0.0114 0.8977 0.0909

0.0938 0.8063 0.1000

———————————————

B=2, A influence on C

val =

109.4391

expected =

4.9286 8.5714 31.5000

18.0714 31.4286 115.5000

chi2 =

20.5807 39.6214 25.7857

5.6129 10.8058 7.0325

p =

0

prob =

0.3333 0.6000 0.0667

0.0485 0.0788 0.8727

ANSWER: YES THERE IS AN INTERACTION EFFECT

————————————–

A=0, B influence on C

cont =

14 65 9

71 209 14

1 79 8

30 258 32

15 27 3

8 13 144

val =

27.3861

expected =

11.9457 68.0905 7.9638

11.9457 68.0905 7.9638

6.1086 34.8190 4.0724

chi2 =

0.3533 0.1403 0.1348

10.0294 1.7479 0.0002

12.9419 1.7558 0.2824

p =

1.6608e-05

prob =

0.1591 0.7386 0.1023

0.0114 0.8977 0.0909

0.3333 0.6000 0.0667

————————————————

A=1, B influence on C

val =

477.8984

expected =

41.1374 181.1553 71.7073

44.7754 197.1759 78.0488

23.0873 101.6688 40.2439

chi2 =

21.6780 4.2799 46.4407

4.8757 18.7628 27.1688

9.8594 77.3311 267.5021

p =

0

prob =

0.2415 0.7109 0.0476

0.0938 0.8063 0.1000

0.0485 0.0788 0.8727

ANSWER: YES THERE IS AN INTERACTION EFFECT

ANSWER from both analyses: YES THERE IS AN INTERACTION EFFECT

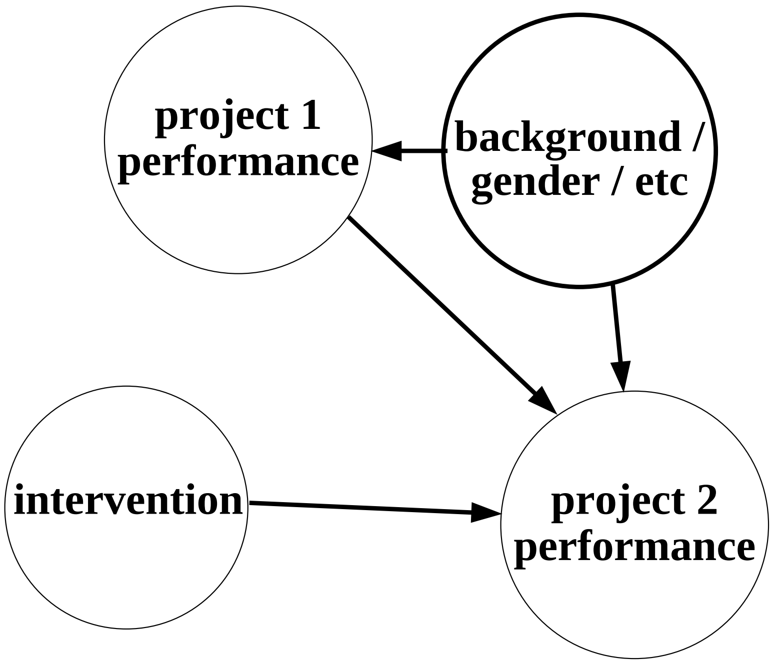
Question 3

The file *assessment.xls* contains data collected from a recent classroom study. For each of two projects (labeled *A* and *B*), groups were assessed using three different types of metrics: *quality, originality* and *elegance.* For each metric, groups were compared to the population of "all" computer scientists (*absolute* measure) and their classroom peers (*relative*). For each of these six measures, groups were assigned a score from one (lowest) to five (highest).

Project A was performed first, followed by project B. Between the two projects, an intervention was performed. The intervention included a different way of defining and explaining the project.

We would like to argue that 1) the students performed better on project B than project A in these metrics, and 2) the intervention was responsible for this improvement.

1. (10pts) Draw an abstract graphical model that captures this hypothesis and expresses the relationships between the key variables. You may compress the performance metrics into a smaller set of metrics and you many introduce other reasonable variables.



2. (20pts) Do the students perform better in project B than in project A? Make this argument in detail, including appropriate hypothesis tests.

Using a paired 2-tailed t-test for each of the six questions:

h =

0 0 1 0 0 0

p =

0.2465 0.7308 0.0387 0.1476 0.0709 1.0000

So: only absolute originality sees a statistically significant difference. (with multiple comparisons, we should treat this result with caution)

3. (10pts) What do you conclude about the hypothesis?

   While the intervention could have had an effect, this effect could be due to alternative hypotheses.