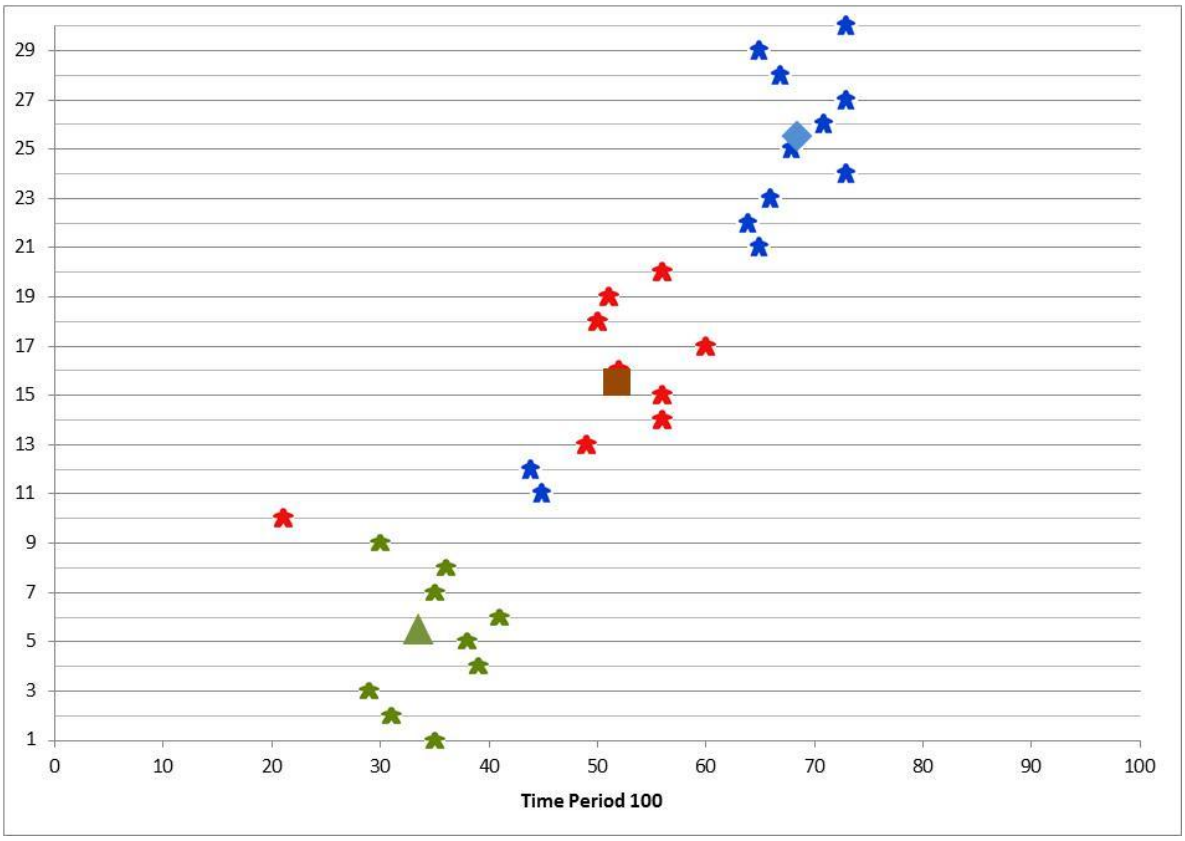
MGT 5155 A: TOPICS IN BUSINESS ANALYTICS
Wake Forest University MBA: Fall 2013

Jonathan P Pinder PhD • pinderjp@wfu.edu • 336 Farrell Hall



Objectives:

1) To develop a high level business analytics modeling process using data mining, predictive modeling, and agent-based models.
2) To learn specific statistical techniques for predictive modeling.
3) To learn specific simulation techniques for agent-based modeling.

Grading:

Mid-term Exam:	40%	September **17**, 2013
Final Exam:	60%	October **15**, 2013

Exams:

Both the Mid-term and Final exams will consist of a take-home component and an in-class component (3-5 short questions). The take-home components will consist of 2-3 problems, similar to the homework exercise sets discussed in class.

Class Participation:

You are expected to attend all classes prepared to ask questions, provide answers, and take an active part in the learning process. Read and be prepared to discuss the exercise sets. Class discussions will center on the examples in the exercise sets, so you are expected to be thoroughly prepared to discuss each example and exercise set. Your questions and comments should demonstrate that you have thoroughly read and synthesized the assigned material. Failure to fully participate, especially due to lack of preparation, will result in at least a THREE level downward adjustment to your final grade (e.g., A to B, B+ to C+, C+ to F, etc.).

Grade Definitions:

Letter grades will be assigned according to the following values:

Grade	Value	Description
A	94%	
A-	90%	**Proficient**: All major and minor managerial and learning issues achieved
B+	86%	
B	82%	**Competent**: Most major and most minor managerial and learning issues achieved
B-	78%	
C+	74%	**Literate**: Several major and many minor managerial and learning issues NOT achieved
C	70%	
F	0%	**Not Competent**: Student is unprepared for advanced work

Readings:

Excerpts from::
Business Statistics, A First Course, by Sharpe, De Veaux, and Velleman, 2011
The Practice of Statistics for Business and Economics, 3rd Edition, by Moore, McCabe, Alwan, Craig, Duckworth, 2011
Data Mining In Excel, by Shmueli, Patel, and Bruce, 2005 (or newer)
Applied Logistic Regression, 2nd Edition, Hosmer and Lemeshow, 2000
Agent-Based Models, by Nigel Gilbert, Sage Publications, 2008, ISBN (0-324-32359-X)

are provided on *Sakai*.

Office Hours:

Tuesdays and Thursdays: 2:30 – 4:00

Laptops & Cell Phones:

The use of laptops, cell phones, and other web-enabled devices in class is prohibited at all times. There will be no exceptions.

Honor Code:

The class is conducted in accordance with the Wake Forest University honor code. I assume that there will be no cheating and that students act responsibly and professionally during exams. Any violations will result in an immediate F for the course as well as consequences as imposed by the Honor Council.

More specifically, it is imperative that students discover the learning process in their own fashion. Therefore, for this course, the following actions will also result in failing this course:

1) To ask for, or otherwise seek, class materials from students, or others, who have previously taken this class.
2) To accept class materials from others who have previously taken a similar class.
3) Conveying information regarding exams.

"Class materials" include, but are not limited to notes, exams, quizzes, spreadsheets (or other software), or other forms of written or verbal "solutions".

Learning Assistance Center:

If you have a disability or need special consideration, please contact the Learning Assistance Center at 758-5929 in the first 2 weeks of class.

Emergency Course Continuation Plan:

1. Continue to read all materials and lecture notes as indicated in the syllabus. Be sure to download all class material onto your computer or onto a CD/DVD so that you will have access to it in case of internet connectivity interruptions during an emergency.

2. Write answers to the learning objectives for each class (100-150 words each). Submit to the appropriate professor as soon as feasible via email. If internet resources are not available, send via regular post office mail to:

   Jonathan P. Pinder
   School of Business
   Wake Forest University
   PO Box 7897
   336 Farrell Hall
   Winston-Salem, NC 27109

3. If both email and U.S. Postal Service are interrupted for a period of time, complete the assignments above in a timely manner and hold the written material until communications methods are restored.

BUSINESS ANALYTICS 2 - SCHEDULE – Fall 2013

Session	Date	Day	Module	Topic	Readings	Assignment
1	Aug 27	Th	**Data Mining:** Exploring the data	Overview: Data Mining, Predictive Modeling, & Optimization	Intro to Data Mining	
2	Aug 29	T		Data Mining	Credit Scoring Example	*Pilot Bank*
3	Sept 3	Th	**Logistic Regression:** Probabilities from data	Logit & MLE estimation	A Good Lead Is Hard To Find; SPB: Example 8.2.1 Personal Loan p.133	*Logistic Regression Exercises*
4	Sept 5	T			Ch 1 H&L	*Logistic Regression Exercises*
5	Sept 10	Th		Multinomial MLE estimation	Ch 8 H&L	*Multinomial Logistic Regression Exercises*
6	Sept 12	T		Application		*Multinomial Logistic Regression Exercises*
7	**Sept 17**	**Th**	**Midterm Exam**			
8	Sept 19	T	**Agent-Based Models:** Using probability to make optimal decisions	Intro To ABM	Gilbert; Agent-Based Models	*NetLogo Examples*
9	Sept 24	Th		Simulating Individuals (Agents)	Macal & North; Tutorial on Agent-Based Modeling	*ABM I*
10	Sept 26	T				*ABM I*
11	Oct 1	Th		Developing ABMs	*WSJ* Facebook &St. Petersburg Paradox	*ABM II*
12	Oct 3	T				*ABM II*
13	Oct 8	Th		Using Agents to optimize		*ABM Optimization*
14	Oct 10	T				*ABM Optimization*
15	**Oct 15**	**Th**	**Final Exam**			

Data Mining Exercises

Type I Error = Probability of a *False Positive*. Type II Error = Probability of *Failure to Detect*.

1. One percent of people at age 40 who participate in routine cancer screenings have cancer. 80% of people with cancer will get positive screenings. 10% of people without cancer will also get positive screenings. This type of question has been asked of physicians and medical students with very small proportion of them answering correctly.

a. Construct a contingency table for this problem and draw a probability tree for this problem.

b. In a routine screening, a person in this age group had a positive screening. What is the probability that the person actually has cancer?

c. State relevant joint, marginal and conditional probabilities for this problem and their managerial relevance

d. Identify the Type I and Type II errors, their probabilities, and their consequences.

2. There is a controversy over the practice of insurance companies using credit ratings as an input to determining car insurance premiums[1]. Consider this information: 2% of those insured file a claim. 90% of claims are filed by customers with bad credit ratings. Of the customers who do not file claims, 95% have good credit ratings.

a) The probability of a Type I Error =

b) Given a good credit rating, the probability of a customer filing a claim =

c) Managerial interpretation of a) & b) is:

1: http://bucks.blogs.nytimes.com/2011/06/22/want-to-pay-less-for-car-insurance-have-good-credit/

Logistic Regression Exercises

$y = \frac{e^{(\beta_0 + \beta_1 x)}}{1 + e^{(\beta_0 + \beta_1 x)}} = \frac{1}{1 + e^{-(\beta_0 + \beta_1 x)}}$; y is the cumulative probability of an event; usually estimated as the proportion belonging to a specific group.

1. Car Max would like to develop a predictive model to determine the likelihood of demand for various cars. For a sample of customers, gender, marital status, age were recorded and 3 attributes of the cars purchased: country of manufacture, size of car, and type of car. Initially, you are interested in the relationship between gender and country of manufacture. Here are the results from the 303 consumers. Use both a Chi-Square and a logistic regression to analyze the relationship between gender and country of manufacture.

	Gender	
Country	Female	Male
US	54	61
Other	84	104

2. A study compared demographic characteristics of people who use the Internet for travel arrangements and of people who do not. Of 1132 Internet users, 643 had completed college. Among the 852 nonusers, 349 had completed college. Use both a Chi-Square and a logistic regression to analyze the relationship between college and Internet usage.

3. 1,000 homes were given coupons for a product. The coupons offered different price reductions ($0.25, $0.50, $0.75, $1.00, and $1.50). 200 homes were randomly appointed to each of the price reduction levels. The number of coupons redeemed is given below. Estimate a logit model to test whether coupon value is a significant factor in for coupon redemption, and determine the critical coupon value at which consumers are more likely than not to redeem the coupon. What other factors would you consider in developing an optimum coupon system/

Coupon Value	Households	Redeemed
0.25	200	32
0.50	200	51
0.75	200	70
1.00	200	103
1.50	200	148

4. The annual incomes of 600 purchasers of Hondas and Acuras are tabulated below. Estimate a logit model to test whether annual income is a significant factor in buyer preference, and determine the critical income at which buyers are more likely to purchase an Acura than a Honda.

Product	Income	Count
Honda	35	138
Acura	35	12
Honda	45	145
Acura	45	25
Honda	55	58
Acura	55	47
Honda	65	36
Acura	65	49
Honda	75	27
Acura	75	63

5. 20 highway construction contracts were discussed during a trial and several were determined, through corroborating testimony, to be colluded. Use the ratio of the contractors' bids to the state Department of Transportation estimated cost (including profit) to build a logit model to estimate the probability of a contract being rigged. What is your critical value? What are some of the problems associated with building and using this model?

Collusion	Bid/Est ratio
no	1.03832394
no	1.04678272
no	0.97692481
no	0.92547517
no	0.96356347
no	0.98367323
yes	1.06244465
yes	1.32546552
no	0.91998217
yes	1.01491127
no	1.00146506
no	0.96446551
no	0.92746178
no	0.89338949
yes	1.17891914
no	1.10371689
no	1.03111041
no	1.12453782
no	1.0364084
yes	1.19791717

6. Investors and marketing managers are interested in predicting whether a movie will be profitable based on the opening-weekend revenue. Whether a movie was profitable and the revenues from the opening weekend of the movies showing are listed below. Estimate a logit model to test whether the natural log of opening-weekend revenues is a significant factor in determining whether a movie will be profitable, and determine the critical Revenue at which movies are more likely to be profitable than not.

obs	Opening	Profit	obs	Opening	Profit
1	12.053131	0	21	16.328506	0
2	85.558731	1	22	102.335066	1
3	91.774413	1	23	20.220412	1
4	11.112632	0	24	68.033544	1
5	44.04144	0	25	47.743273	0
6	23.075892	0	26	40.011365	1
7	18.533765	0	27	135.634554	1
8	9.317371	0	28	25.723815	0
9	38.32916	0	29	23.624548	0
10	72.629713	1	30	20.574802	0
11	11.528498	0	31	12.778913	0
12	14.574213	1	32	151.116516	1
13	21.406781	0	33	27.476745	1
14	16.728411	0	34	74.036787	1
15	30.061756	1	35	48.475154	1
16	36.045301	1	36	5.951409	0
17	108.435841	1	37	17.135055	0
18	47.60648	1	38	70.25171	1
19	47.224594	1	39	27.515871	0
20	17.453216	0	40	25.783232	0

Multinomial Logistic Regression Exercises

$y_j = \frac{e^{(\beta_{0j} + \beta_{1j} x)}}{\sum_j e^{(\beta_{0j} + \beta_{1j} x)}}$; y is the cumulative probability of an event; usually estimated as the proportion belonging to a specific group.

1. The *CreditScore* data lists the credit score and the associated loans status for each account. A closed account can be classified as one of 4 states: term (paid in full through all payments), prepaid (paid in full before term), arrears (behind in payments but not defaulted, future payments may resume), default (payments have ceased and will not continue).

    a. Estimate a predictive model based on the credit scores.

    b. Calculate the probabilities for each state, and most likely state, for each credit score.

2. Amazon uses various types of data to predict which products will appeal to various customers. The *ProductChoice* data lists the gender and total expenditures at Amazon for the previous 12 months for a sample of 63 customers. Use this data to estimate a predictive model for brand preference.

    a. Estimate the main effects models and the model with interaction.

    b. If a female has spent $250 in the past 12 months, which type of product is she most likely to buy? Calculate the specific probability of buying each type of product.

    c. Which groups/expenditures have the highest probability of buying books?

3. The *BrandPref* data lists region, income, and brand of product for a sample. Use this data to estimate a predictive model for brand preference.

    a. Estimate the main effects models and the model with interaction.

    b. If a family from the east has an annual income of $72,000, which product is the family most likely to buy? Calculate the specific probability of buying each product.

    c. Which groups/income have the highest probability of buying C?

4. Car Max would like to develop a predictive model to determine the likelihood of demand for various cars. For a sample of customers, gender, marital status, age were recorded (*CarPoll* data) and 3 attributes of the cars purchased: country of manufacture, size of car, and type of car.

    a. Using exploratory data analysis, develop an influence diagram and state the major relationships.

    b. Estimate the main effects and interaction models for each car parameter.

    c. Estimate the type of car (include the relevant probabilities) for various age, gender, marital statuses.

NetLogo Examples

View these examples, and consider the following:

a. What are the agents and their attributes?

b. What business settings might the Ecology Examples represent?

c. How might you use Excel to model similar settings?

http://ccl.northwestern.edu/netlogo/models/

Ecology Examples:

Simple Birth Rates	http://ccl.northwestern.edu/netlogo/models/SimpleBirthRates
Altruism	http://ccl.northwestern.edu/netlogo/models/Altruism
Flocking	http://ccl.northwestern.edu/netlogo/models/Flocking
Shepherds	http://ccl.northwestern.edu/netlogo/models/Shepherds
Wolf Sheep Predation	http://ccl.northwestern.edu/netlogo/models/WolfSheepPredation
Cooperation	http://ccl.northwestern.edu/netlogo/models/Cooperation
Life	http://ccl.northwestern.edu/netlogo/models/Life

Probability/Statistics Examples:

Galton Box	http://ccl.northwestern.edu/netlogo/models/GaltonBox
Expected Value	http://ccl.northwestern.edu/netlogo/models/ExpectedValue
Three Doors	http://ccl.northwestern.edu/netlogo/models/ThreeDoors

Business Examples:

Bank Reserves	http://ccl.northwestern.edu/netlogo/models/BankReserves
Team Assembly	http://ccl.northwestern.edu/netlogo/models/TeamAssembly

Agent-Based Modeling Exercises – Set 1

1. **Bayesian Analysis**: A soft drink company employs drivers to deliver products and stock them in grocery stores. Applicants for this position are given a pre-employment test to increase the likelihood of reliability and retention. Test questions are multiple-choice questions and each has five possible answers. Solve this with an Agent-based model. Check your answer with algebra and with Bayes Theorem.

    a. Assume that all guesses are equally likely. If 60% of the respondents got the correct answer, what is the percentage of applicants who actually know the correct answer?

    b. Assume that test takers can rule out 1 answer. If 60% of the respondents got the correct answer, what is the percentage of applicants who actually know the correct answer?

    c. Assume that test takers can rule out 2 answers. If 68% of the respondents got the correct answer, what is the percentage of applicants who actually know the correct answer?

    d. Assume that one of the questions is ruled out by all but 5% and that the other 4 questions are equally likely. If 30% of the respondents got the correct answer, what is the percentage of applicants who actually know the correct answer?

2. **Bayesian Analysis**: A bank is reviewing its credit card policy to ameliorate the default risk for credit cards. In the past, approximately 5% of cardholders have defaulted and the bank has been unable to collect the outstanding balance. Thus management has established a prior probability of 0.05 that any particular cardholder will default. The bank has further found that the probability of missing one or more monthly payments for those customers who do not default is 0.20. Of course the probability of missing one or more payments for those who default is 1.

    a. Given that a customer has missed a monthly payment, calculate the probability that the customer will default.

    b. The bank would like to recall its card if the probability that a customer will default is greater than 0.20. Should the bank cancel a card if the customer misses a monthly payment? Why or why not?

    c. Solve this problem graphically.

    d. Solve this analytically using notation.

    e. Solve this problem with an agent-based simulation.

3. **Bivariate Probability Distribution:** There are two people going to a concert that starts at 9pm. Each person will arrive at the concert independently between 8 and 9pm. Assume their arrival times are independently uniformly distributed over 8-9. Whoever arrives first will wait for the other one outside, so that they can go in to the event together. They also agree to two rules. First, if it is 8:50 and you are waiting, then wait no longer and go in. Second, if you have been waiting for 10 minutes, then wait no longer and go in. What is the probability that the two people will actually meet outside before going in?

    a. Solve this problem with a Monte Carlo simulation.

    b. Solve this problem graphically.

    c. Solve this problem with a graphical simulation.

    d. Solve this problem with an agent-based simulation.

    e. Solve this analytically using notation.

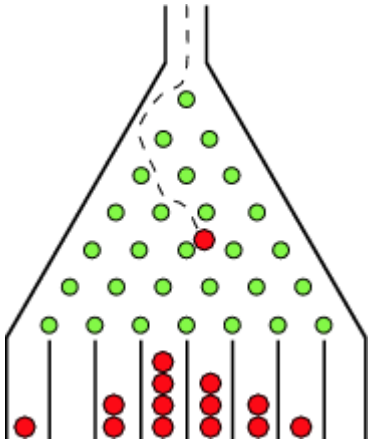
4. **Individual Demand Model:** A local dairy supplies 150 local restaurants with ice cream for their desserts each week. The ice cream is produced once a week before orders are taken and cannot be stored for longer than a week (unsold must be discarded). How much ice cream should be produced each week if the selling price to restaurants is $10/gallon and the cost to the dairy is $6.50/gallon?

   a. Suppose each restaurant has a 30% chance of ordering a gallon of ice cream each week. How much ice cream should be produced?

   b. Suppose the restaruants are grouped according to their level of demand and their probabilities of ordering a gallon of ice cream each week are given in the table below. How much ice cream should be produced?

Number of Restaurants	Prob(Order 1 gallon)
25	10%
30	20%
45	30%
35	40%
15	50%

5. The **Galton Board**, also known as a *quincunx* or bean machine, is a device for statistical experiments named after English scientist Sir Francis Galton. It consists of an upright board with evenly spaced nails (or pegs) driven into its upper half, with the nails arranged in staggered order, and a lower half divided into a number of evenly-spaced rectangular slots. The front of the device is covered with a glass cover to allow viewing of both nails and slots. In the middle of the upper edge, there is a funnel into which balls can be poured, where the diameter of the balls must be much smaller than the distance between the nails. The funnel is located precisely above the central nail of the first row so that each ball, if perfectly centered, would fall vertically and directly onto the uppermost point of this nail's surface. The figure below shows a stylized version of a Galton Board; see http://www.youtube.com/watch?v=9xUBhhM4vbM for an actual Galton Board in action.



   Each time a ball hits one of the nails, it can bounce right (or left) with some probability p (and 1-p). For symmetrically placed nails, balls will bounce left or right with equal probability.

   Thus, this process gives rise to a binomial distribution of in the heights of heaps of balls in the lower slots. If the number of balls is sufficiently large, then according to the *Central Limit Theorem*, the distribution of the heights of the ball heaps will approximate a normal distribution.

   a. Construct a Galton Board as an agent based simulation.

   b. What statement in the Central Limit Theorem creates the Normality exhibited in the Galton Board?

6. In 1989 *Money* magazine assessed the performance of 277 mutual funds over the previous 10 years. For each of the 10 years, they determined which funds performed better than the S&P 500. The research showed that five of the 277 funds performed better than the S&P 500 for eight or more of the 10 years. Investment portfolios constructed by blindfolded monkeys throwing darts at the Wall Street Journal, have a 50% probability of performing better than the S&P 500.

   a. Create an agent-based simulation to determine the number of Monkey funds that would be expected to outperform the S&P 500.

   b. How does this problem relate to the Galton Board?

   c. Use the insight of c. to solve the problem analytically.

7. A miner is trapped in a mine containing three doors. The first door leads to a tunnel that will take him to safety after three hours of travel. The second door leads to a tunnel that will return him to the mine after five hours of travel. The third door leads to a tunnel that will return him to the mine after seven hours. (from *Introduction to Probability Models 10th edition*, Sheldon Ross)

   a. Assume that the miner marks the doors before he enters a tunnel so as to avoid re-entering the tunnel later, what is the expected length of time until he reaches safety?

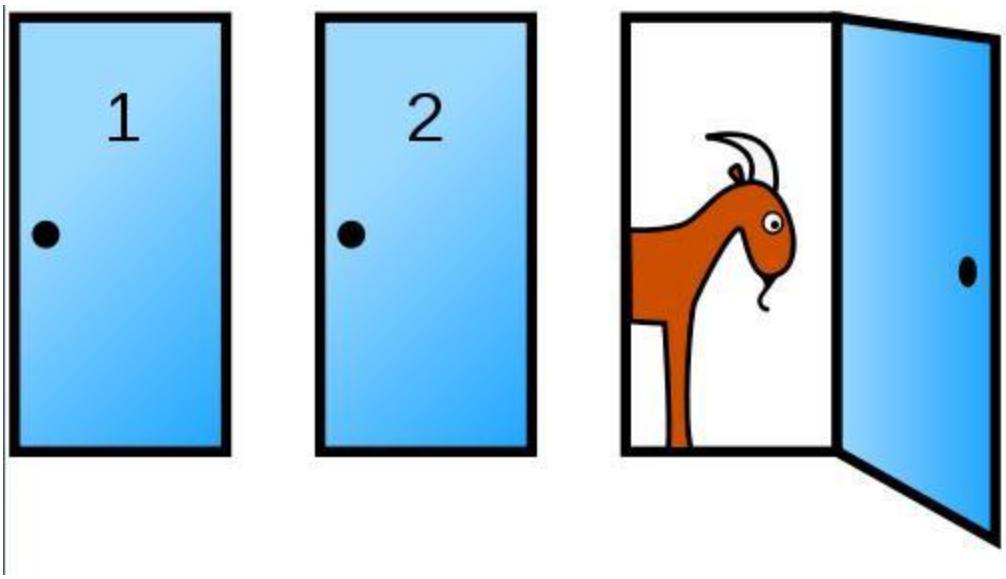
   b. Assume that the miner is at all times equally likely to choose any one of the doors (dope … this is the original problem statement), what is the expected length of time until he reaches safety?

8. The Monty Hall problem is a probability puzzle loosely based on the American television game show *Let's Make a Deal*. The name comes from the show's original host, Monty Hall.

   The problem was originally posed in a letter by Steve Selvin to the American Statistician in 1975. A well-known statement of the problem was published in Marilyn vos Savant's "*Ask Marilyn*" column in *Parade* magazine in 1990:

   Suppose you're on a game show, and you're given the choice of three doors: Behind one door is a car; behind the others, goats. You pick a door, say No. 1, and the host, who knows what's behind the doors, opens another door, say No. 3, which has a goat. He then says to you, "Do you want to pick door No. 2?" Is it to your advantage to switch your choice?

   (http://en.wikipedia.org/wiki/Monty_Hall_problem)



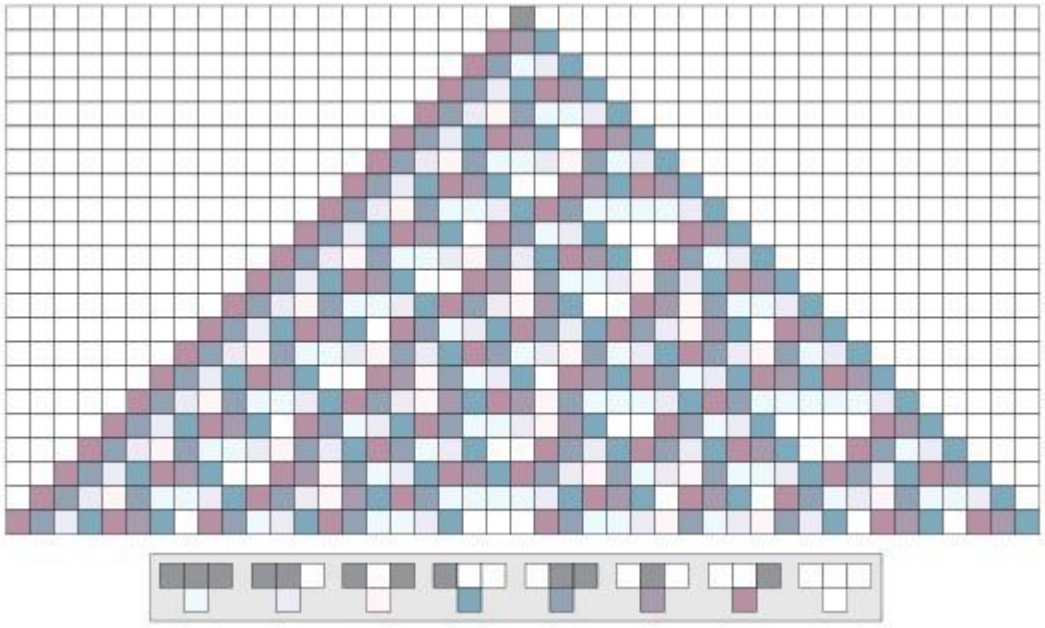
a. Construct an agent based simulation to determine the optimum strategy for this problem.

b. Suppose that the winning prize is worth $100 … determine what loss would make the expected value = $0 (thus making this a "fair game" using simulation.

c. Show what happens if some agents can observe other groups and learn or become discouraged.

9. A **cellular automaton** (pl. cellular automata, abbrev. CA) is a discrete simulation model that consists of a regular grid of cells, each in one of a finite number of states, such as "On" and "Off. The grid can be in any finite number of dimensions. For each cell, a set of cells called its neighborhood (usually including the cell itself) is defined relative to the specified cell. For example, the neighborhood of a cell might be defined as the set of cells a distance of 2 or less from the cell. An initial state (time *t*=0) is selected by assigning a state for each cell. A new generation is created (advancing *t* by 1), according to some fixed rule (generally, a mathematical function) that determines the new state of each cell in terms of the current state of the cell and the states of the cells in its neighborhood. For example, the rule might be that the cell is "On" in the next generation if exactly two of the cells in the neighborhood are "On" in the current generation; otherwise the cell is "Off" in the next generation. Typically, the rule for updating the state of cells is the same for each cell and does not change over time, and is applied to the whole grid simultaneously, though exceptions are known. One example, known as Rule 30, is shown in the figure below

   (http://www.wolframalpha.com/input/?i=rule+30):



   a. Construct Rule 30 in Excel.

   b. Check your answer in part a. using the formula: =MOD((X7 + Y7 +Z7 + Y7*Z7),2) for cell Y8 and copying the formula down.

   c. Think of 4 business models in which such a CA might represent a simulation.

   d. Look up an online version of John Conway's game Life. Think of 4 business models in which such a CA might represent a simulation.

References:

http://mathworld.wolfram.com/CellularAutomaton.html

http://en.wikipedia.org/wiki/Cellular_automaton

Agent-Based Modeling Exercises – Set 2

1. An analyst for a computer firm is trying to determine the optimum price for new e-reader. The variable cost of the e-reader is $50. As an experiment, 200 units for each of 6 price points were offered in 6 similar test markets (see table below). Develop an agent-based model to determine the optimum price and quantity based on the price/quantity pairings given below:

Price	Quantity Sold
$100	65
$125	54
$150	41
$175	30
$200	27
$225	24

2. **St. Petersburg Paradox:** A person tosses a fair coin until a tail appears for the first time. Each time a heads comes up – before the game ending tail – the pot is doubled. Thus, if the initial pot is $1 and the tail appears on the nth flip, the person wins $2n-1. Let X denote the player's winnings (*from Introduction to Probability Models 10th edition* by Sheldon Ross), also see:

   "Facebook and the St. Petersburg Paradox," *Wall Street Journal* Feb. 4, 2012 (in the readings pdf)

   http://en.wikipedia.org/wiki/St._Petersburg_paradox#The_paradox)

   a. What is the expected value of this game?

   b. What would be a 'fair' price to enter this game?

   c. Would you be willing to pay $50,000 to play each game if you could play for as long as you liked and only have to settle up when you stopped playing?

3. **Kelly Betting** (from *Fortune's Formula* by William Poundstone): Consider a game in which each play you are offered a gamble with 2/3 probability of winning and 1/3 probability of losing. You may bet any positive amount you like, provided you have it. The amount you bet is either doubled or lost, independently each play. This gamble is only offered for 20 plays. Construct an agent-based model to determine how much should you bet on each play?

4. **An Insurance Risk Model** (from *Simulation 3rd edition* by Sheldon Ross): Construct an Agent-Based model of an insurance company using the following conditions:

   - The initial number of customers is $n_0 = 500$.
   - The initial capital is $a_0 = \$5{,}000{,}000$.
   - There is a 1% chance that non-customers will become customers. A possible alternative assumption is that new customers sign up according to a Poisson processes with a common rate $\lambda_{arrival}$ = 15/month
   - Each policyholder pays the insurance firm at a fixed rate $c = \$100$ per month.
   - Customers in this risk class average 1 claim about every 2 years and that each claim amount has distribution $N(\mu, \sigma^2) = N(\$10{,}000, \$500^2)$.
   - Policyholders remain with the insurance firm for an average of 36 months.

   a. Create an Agent-Based Model to estimate the probability that the firm's capital is always nonnegative at all times up to Time *T*

   b. How would you determine a 'fair' rate to charge for *c*?

   c. The range over which the model parameters are stable; *i.e.,* at what point does the models behavior significantly change as the model parameters change?

Agent-Based Modeling Optimization Exercises

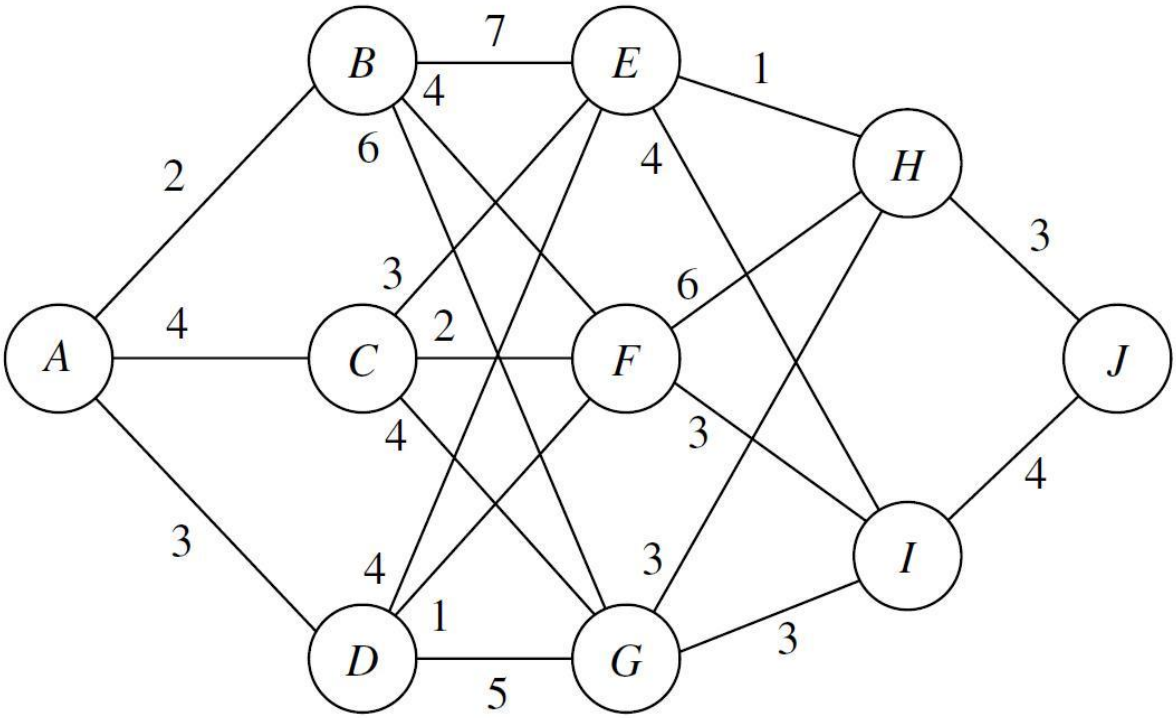
1. **Knapsack problems** are applied to decision-making processes such as the finding the least wasteful cutting of raw materials, selection of capital investments and financial portfolios, selection of assets for asset-backed securitization.

   As an example, consider the situation of getting lost while hiking in the wilderness. The table below shows all of the items that are available to you that will aid you in your hike out of the wilderness. Containers of food and water will give you energy; shelter will protect you from the elements; and defense will protect you from wild animals. Each item has a weight (lbs) and survival points. You must take one item from each category. Unfortunately, the backpack you have has a maximum capacity of 25 lbs. Your chance of survival is calculated by adding all of the survival points together from the items you choose to take with you. Construct an Agent-Based Model to determine the optimum knapsack load. Extra Credit: Cite the source for "Emotional Knapsack".

Category	Weight (lbs)	Survival (points)
Food	5	10
	8	20
	12	25
Water	3	10
	5	20
	8	25
Shelter	5	5
	8	15
	12	20
Defense	1	5
	2	15
	3	20

2. The **stagecoach problem** (*shortest route problem*) is a classic problem in dynamic programming. It was developed by Professor Harvey M. Wagner while he was at Stanford University. It concerns a mythical fortune seeker in Missouri who decided to go west to join the gold rush in California during the mid-19th century. The journey would require traveling by stagecoach through unsettled country where there was serious danger of attack by marauders. Although his starting point and destination were fixed, he had considerable choice as to which states (or territories that subsequently became states) to travel through en route. The possible routes, and their corresponding distances, are shown in the diagram below, where each state is represented by a circled letter.

   Thus four stages (stagecoach runs) were required to travel from his point of embarkation in state ***A*** (Missouri) to his destination ***J*** (California).



   This fortune seeker was a prudent man who was quite concerned about his safety. After some thought, he decided the safest route would be the shortest route (the distances are also shown in the diagram). Construct an Agent-Based Model to determine the optimum route. For further reading, Google *Shortest Route Problem*.

3. A company will soon be introducing a new product into a very competitive market and so is currently planning its marketing strategy. The decision has been made to introduce the product in three phases. Phase 1 will feature making a special introductory offer of the product to the public at a greatly reduced price to attract first-time buyers. Phase 2 will involve an intensive advertising campaign to persuade these first-time buyers to continue purchasing the product at a regular price. It is known that another company will be introducing a new competitive product at about the same time phase 2 will end. Therefore phase 3 will involve a follow-up advertising and promotion campaign to try to keep the regular purchasers from switching to the competitive product.

   A total of $5 million has been budgeted for this marketing campaign. The problem now is to determine how to most effectively allocate this money to the three phases. Let $\boldsymbol{m}$ denote the initial share of the market expressed as a percentage attained in phase 1, $\boldsymbol{f_2}$ the fraction of this market share that is retained in phase 2, and $\boldsymbol{f_3}$ the fraction of the remaining market share that is retain in phase 3. Given the data outlined below, create an agent-based model to determine how to allocate the $5 million to maximize the final share of the market for the new product, i.e., to maximize $\boldsymbol{m(f_2)(f_3)}$.

   a. Assume that the money must be sent in integer multiples of $1 million in each phase where the following table gives the estimated effect of expenditures in each phase:

Millions of dollars expended	m	Effect on market share f_2	f_3
0		0.30	0.50
1	10	0.50	0.70
2	15	0.70	0.85
3	22	0.80	0.90
4	27	0.85	0.93
5	30	0.90	0.95

   b. Now assume that any amount within the total budget can be spent in each phase, with the estimated effect of spending an amount x_i (in millions of dollars) in phase i (i = 1, 2, 3) is:

   $m = 10x_i - x_i^2$

   $f_2 = 0.40 + 0.10x_2$

   $f_3 = 0.60 + 0.07x_3$