Math Discovery

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Introduction

Math is all around us! It is the numbers that science creates, allowing us to use statistical information (studied/analytical info) in various models. For this project, Markov models were used to describe the diffusion of an epidemic. Probability and statistics were used to calculate the probabilities and relationships that will deem you victorious in a game of chance and even create simulations that provide precision. Through the course of the research, Hazard Prediction and Assessment Capabilities (HPAC) was explored, aiding in the study of impacts of chemical, biological, radiological, and nuclear weapons detonation in any area in the world.

Background

Within math, statistics is a field dealing with acquiring and analyzing data. It is used in everyday things like predicting the weather and how different sports teams will perform. Statistics and probability, a subset of statistics, are used in a variety of situations. One is the game Pass the Pigs, where players roll two pigs and gain points based on the landing. Another is in Markov chains, like the Susceptible, Exposed, Infected, Recovered/Removed (SEIR) model, which models spread of diseases through a population. A Markov chain describes a series of states in which the probability of each event only depends on the previous state. Lastly, probability and statistics is used in HPAC, a program used to model the spread and deadliness of chemical bombs dropped at specific locations and times.

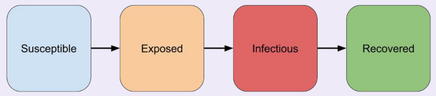

Figure 1. A SEIR model that uses Markov chains. This assumes that recovered individuals will have immunity; if this was not the case, there would be an arrow from recovered to susceptible.

Materials and Methods

Materials for Pass the Pigs

- Toy Pigs
- Excel spreadsheets

Materials for SEIR Model/Markov theory

- Website about markov's process
- Disease simulations

Materials for HPAC

- Laptop (HPAC software)
- Google Earth Pro

Methods for Pass the Pigs

- Rolling pigs for 100 trials
- Typing results into excel spreadsheets
- Looking over and studying data about statistics

Methods for SEIR Model/Markov Chain

- We studied diseases and their spread
- Changed probabilities for markov model

Methods for HPAC

- Inputting the what, where, when, and weather into simulation
- Studying outcome of chemical weapon
- Converting image of weapon attack onto google earth

SECOND PIG

FIRST PIG	DU	DD	T	R	Sn	LJ
DU	53	47	9	47	1	1
DD	56	85	14	80	2	1
T	15	20	7	22	0	0
R	49	81	16	70	1	2
Sn	3	6	3	3	0	0
LJ	2	1	1	2	0	0

0		0.15	DD	478	0.34
1		0.20	DU	335	0.24
5		0.45	T	114	0.08
10		0.07	R	443	0.32
15		0.02	Sn	19	0.01
20		0.12	LJ	10	0.01

Figure 2a: Results. The small dataset from Pass the Pigs, showing 0 results in the LJ row and column.

Results

The SEIR model simulation of the flu was set up based on collected data. Two simulations were run; one with a large amount of data and one with a small amount. The game pass the pigs was also run to collect data on the likelihood of each roll.

Large Dataset

- SEIR Model
  - Gives a specific percentage of the separate steps.
  - Results show a 0.1% death rate, which is identical to the 0.1% death rate collected from data on the American population.
- Pass the Pigs
  - Shows a more accurate amount of data that had results for all possible results.
  - Results showed all sides and allowed for the needed result to be obtained.

Small Dataset

- SEIR Model
  - Gives surface level results of the separate steps that were not accurate.
  - Results showed a 17% death/removed rate compared to the actual 0.1% death rate, which overemphasizes how bad the virus actually is.
- Pass the Pigs
  - Shows averaged data that was missing data and had results that differed greatly from the total average data.
  - Results showed no results, or 0%, in the 'Leaning Jowler' roll compared to the 0.07% of the average. It also showed an abnormally high 'Double Side' roll.

The comparison of the two results showed that a small amount of data cannot get an accurate result and can miss entire parts, which can undermine the results.

0.1	0.9	0	0	0
0.9	0	0.1	0	0
0	0	0	0.999	0.001
0.9	0	0	0.1	0
0.01	0	0	0	0.99

State statistics

Steps: 100

	0	1	2	3	4
Visits	40	38	3	2	17
Visits (%)	40%	38%	3%	2%	17%

Figure 3a. A SEIR model with 100 cases. The percentage shows the probability of of how many people are in each in section.

0.1	0.9	0	0	0
0.9	0	0.1	0	0
0.	0	0	0.999	0.001
0.9	0	0	0.1	0
0.01	0	0	0	0.99

State statistics

Steps: 100000

	0	1	2	3	4
Visits	47850	43043	4236	4769	102
Visits (%)	48%	43%	4%	5%	0%

Figure 3b. A SEIR model with 100,000 cases. Similar to Figure 3a.

SECOND PIG

FIRST PIG	DU	DD	T	R	Sn	LJ
DU	8	8	0	7	0	0
DD	8	5	6	9	0	0
T	0	1	0	3	0	0
R	5	18	2	15	0	0
Sn	0	5	0	0	0	0
LJ	0	0	0	0	0	0

0		0.16	DD	65
1		0.13	DU	44
5		0.46	T	12
10		0.1	R	74
15		0	Sn	5
20		0.15	LJ	0

Figure 2b: Results. The large dataset from Pass the Pigs, showing multiple results in the LJ row and column.

The HPAC models set up allowed for multiple experiments to discover the optimal attack. The points put in – such as direction and speed of wind – allowed for calculation to be done by the computer to simulate an actual bomb attack. The results would allow for preparation in order to fend off an actual attack.

Conclusion

These models can vary, however, based on compiled data and experiments, these models were able to provide mathematical equations/formulas that generated an accurate prediction for success, leading to the conclusion that all models deal with a certain aspects of life connecting to the fact that they all use statistics to solve a variety of real-world problems.

HPAC - The Defense Threat Reduction Agency using statistics and simulations can most likely mitigate the chances of a CBRN/industrial incident, lessening the chances of:

- Mass Destruction
- Human Population being harmed

Figure 5. A 3D close up of the Naval Observatory in the HPAC model from Figure 2.

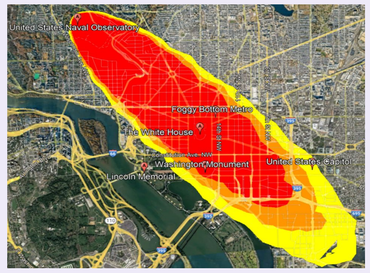

Figure 4. A model from HPAC showing a Missile Bulk of Sarin (a nerve agent) hits the Naval Observatory with a southeastern wind speed of 5mph. Red - 50% Mortality, Orange - 50% Casualties, Yellow - 10% casualties.

Pass the Pigs - The more data that was collected and the more probability and statistics that were used, increase the outcome of winning the game.

SEIR Model - Having a larger data set for this disease model can predict the spread and impact of an viral infection.

Figure 6. Rolling two of the pigs for 100 trial to aid in creating a prediction for Pass the pigs.

Acknowledgments

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