CSE 6730, Group 37 Final Report

Discrete Event Simulation

1 Project Title

Simulation of the Spread of Syphilis within Group Housing for the Elderly

2 Team Members

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3 Problem Description and Purpose

More and more communities of the elderly are suffering from outbreaks of sexually transmitted infections [8]. According to Athena Health, patients over 60 account for the biggest increase of in-office treatments for sexually transmitted infections.

For this study, we are going to focus on syphilis, but the methodology and resulting simulation could easily be applied to other treatable, non-deadly STIs like chlamydia and gonorrhea.

There are several factors that have led to the spread of STIs among older people (especially in group housing):

- Lack of safer sex practices (such as condom use) in older individuals. People who became sexually active before AIDS are less likely to follow safe sex practices.
- Imbalances between the number of men and women. In retirement homes, there are typically significantly more women than men. It would not be surprising to find that the few healthy men would act as a nexus for sexually transmitted infections.
- Shame around testing and treatment. Older people (especially married older people) might be reluctant to tell their doctor about symptoms, get tested, and pursue treatment.
- Number of opportunities for transmission. In earlier times, we could expect sexual activity to diminish in the aging population. However, with people living longer, healthier lives and the proliferation of safe erectile dysfunction drugs, people in retirement communities are more sexually active than their parents were at the same age – especially if they live in close community with a large number of potential partners.
- Antibiotic resistance. Old people living in community are likely to get other kinds of bacterial infections, like strep, and take antibiotics. In the past, this was likely to wipe out undiagnosed syphilis (or chlamydia or gonorrhea) as a side-effect. As these STIs have evolved to become more antibiotic resistant, a strep-sized dose of amoxicillin is less likely to do the job.

Discrete Event Simulation (DES) was been used for long time in many healthcare simulation, ranging from health care system operation, disease progression modeling, screening modeling and health behavior modeling [7, 12].

A realistic simulation of the transmission of STIs in retirement homes could be useful in deciding between different interventions. For example, would increasing condom use by 20% be more effective than annual STI tests?

4 Literature review

Propagation of Sexually transmitted diseases (STD) is modelled mainly based on the option of the social network that describes the contact between individuals. Perhaps the initial form of these models was STDSIM, created in the late 1990s and utilised in numerous HIV modelling studies [1].

The network models have become increasingly difficult with the use of information from the populaces under examination. One such model depicts a collection of work around demonstrating the HIV pandemic in Vancouver, which incorporates a system model of infusing drug clients and female sex laborers, with the point of evaluating the viability of various control methodologies.

To model STDs, a network model is generated with an analogy of vertices representing persons and edges representing contacts.A transmission event can happen in cases of connected edges, thus making the probability distribution of the number of edges of each node a very salient feature. Each of the edges can have various weights which directly relate to the type of interactions between the individuals. For instance, the netwrok can be modeled in three levels of interactions that determine heterosexual contact:0, no contact; 1, spousal partnership; 2, non-spousal partnership [3].

Although, this can be very difficult in cases with large datasets as developing models with social networks would need a large number of people to have expertise on the different fields involved like statistics, computer science, ethnography, medicine among others.

An alternative model can be built by considering mainly a few concise statistics regarding the extensive data [13]. These contact networks make way for analysing the break of disease transmissions between persons by the use of condoms and other precautionary measures. This helps understand the impact of superspreaders as well. There are other models of STDs that are based on System Dynamics and other concepts. These are mainly aimed for making decisions on how to allocate resources to reduce STDs in a targeted testing program [6].

5 Data source

We get the data from the Centers for Disease Control and Prevention (CDC) website for parameters on syphilis. This includes:

- Rates in the general population at the ages at which people would enter retirement homes
- Likelihood of transmission for different types of sexual activity (intercourse, oral, anal).
- Time after infection before symptoms appear.

We will also use a local retirement community to be modeled. From that administration we will find out:

- Number of men and women
- Ages at which people enter the community
- Duration that people stay in the community
- What, if any, STI testing and treatment are provided to the residents

Finally, we will do some interviews with residents to create a model of the individual:

- Number of sexual partners per year
- History of STI testing and treatment
- Marital status
- Gender

- Age
- Types of sexual activity that they engage in (if possible)

As an updated, we also successfully obtained the real data about syphilis directly from the CDC through some connections.

6 Methodology

Our simulation will first simulate a population of people entering and exiting a single retirement community. It will use stochastic methods to give them an initial age, gender, and infection status. It will also remove these people as move somewhere else or die. When someone dies or moves away, this creates room for a new resident.

Within that population, we will update each individual's infection status as they become infected and get treated. We will also track if they have become symptomatic. Thus, each time an uninfected person engages in sexual activity with an infected person, we will roll the dice to decide if the uninfected person becomes infected. Each person will be symptomatic for some amount of time before seeking testing and treatment.

We will test different interventions:

- Increasing condom usage
- Periodic testing and treatment of the whole community
- Promoting monogamous fluid bonding
- Working toward equal numbers of men and women in the community

7 Modelling using Discrete Event Simulation

Discrete event simulation is a form of computer based modelling that provides an intuitive and flexible approach to representing complex systems. Our model simulates the dynamics of main, and casual sexual partnerships, with behavioural model parameters estimated form sexual network data.

7.1 Structural development

The core concepts of DES are entities, attributes, events, resources, queues, and time. In disease modeling studies, the network model will generally consist of a set of individuals connected by contacts, where it is assumed that the contacts are such that if a transmission event could take place. The use of the most important feature is how well individuals are connected. In pair-formation models developed by Dietz and Hadeler, Waldstätter, and Kretzschmar and Dietz [2] ,the pair-formation framework allow modeling of differential infection risk among persons who are single or paired, and it has been widely used in a number of other mathematical models of sexually transmitted infections [5, 9, 11, 4].

Our model include compartments that stratify the population by age, sex, partnership status, sexual risk behavior, and infection status. Transmission of sexual disease in the model occurs via unprotected sex in heterosexual partnerships (refer to Fig. 1)

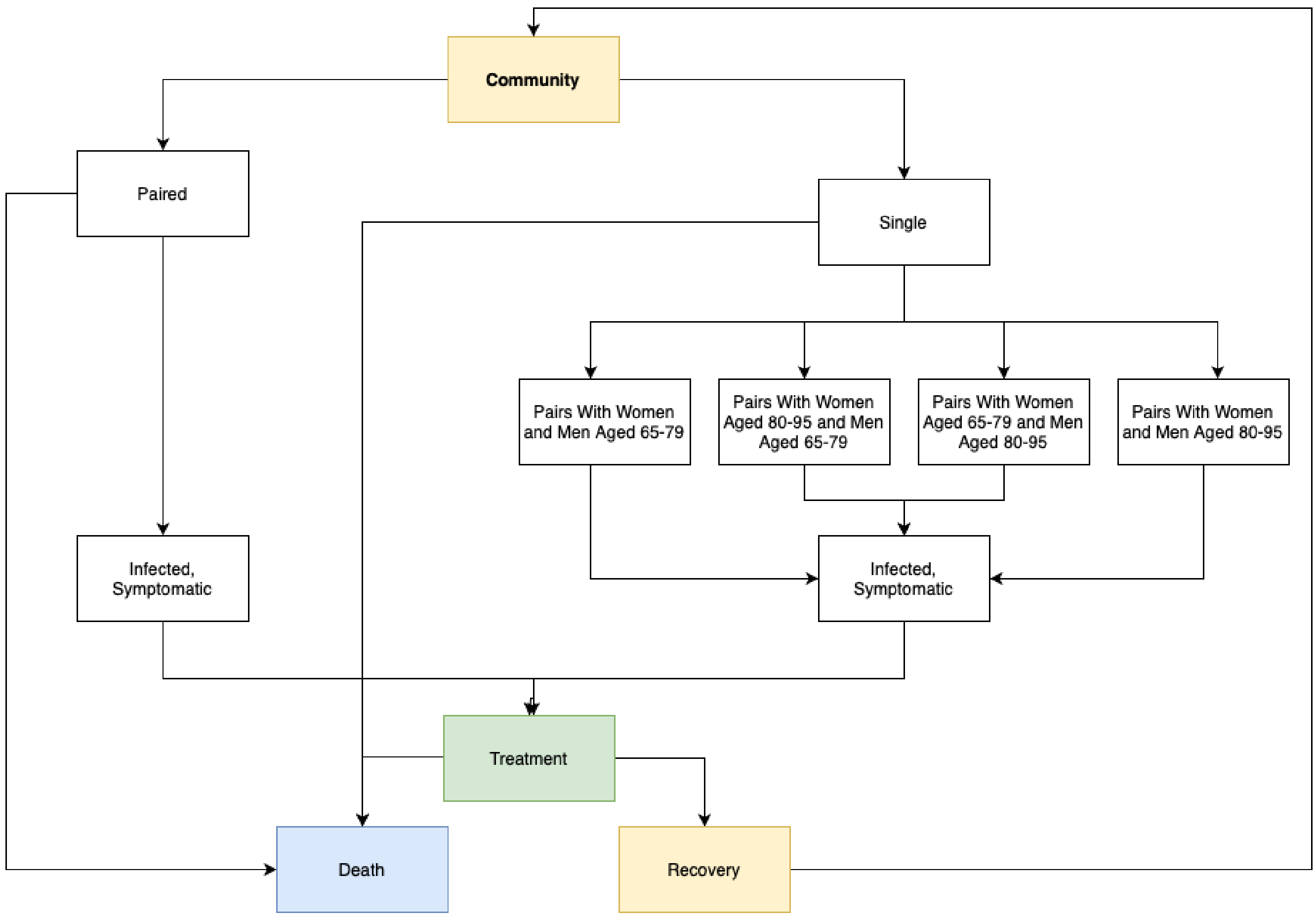
Predictors of partnership formation varies by partnership type,risk level,, age mixing, and status-unknown partnership. In our model, there are 2 partnership statuses that are mutually exclusive. Entity can be part of the unpaired("single")population or paired("married"), unpaired population can have casual partners at age-specific rates. Casual partners represent short term relationships, and they are modeled as instantaneous partnerships. Behavioral parameters were informed by the National Survey of Family Growth. Parameters and their prior distributions [10] are shown in Table 7.1.

Parameter/Variable	Description	Distribution
Population size	Population size for each age group	Uniformly distributed
Time step	Time step implemented in the model	A day
High risk	Fraction of the population defined as high risk	10% (Assumption)
Low risk	Fraction of the population defined as low risk	90% (Assumption)
	Testing symptomatic individuals	
Women	Testing of symptomatic women	1/(52*(0.079+0.072*Beta(4,4)))
Men	Testing of symptomatic men	1/(52*(0.079+0.072*Beta(4,4)))
	Casual partners	
High risk(HR)	Single, 65-79 HR	Beta(3,60)
	Single, 80-95 HR	Beta(3,400)
Low risk(LR)	Single, 65-79 LR	Beta(1,160)
	Single, 80-95 LR	Beta(1,160)
	Among paired	
High risk(HR)	Single, 65-79 HR	Beta(10,70)
Low risk(LR)	Single, 80-95 LR	Beta(10,100)
Treatment success(efficiency of antibiotics)		Beta(190,8)
	Natural recovery	
Women		1/(52*(1.13+0.5*Beta(4,4.969)))
Men		1/(52*(1.13+0.5*Beta(4,4.969)))
Transmission probability	Per act probability	Beta(5.5, 50)

Table 1: Description of parameters governing testing, natural recovery and transmission probability

we chose to fix the fraction of the population defined as high risk at constant 10%, but accommodate uncertainty in levels of risk behavior by varying the partner change rates by relationship states and age, in each of the risk groups. Defining a set proportion of the population to belong to a risk group and varying partner change rates is a modeling convention

Figure 1: Block Diagram of the Simulation



8 Development Platform

The programming language is Python 3. Depends on the suitability of the project, we plan to provide a Jupyter notebook for user interaction, or just a command line execution.

We will use heapq as our priority queue.

8.1 Development

Currently, we have successfully model the World as our simulation environment. We have a set of parameters as per Table 8.1. The parameters will be updated and replaced if more suitable parameters needed.

For checkpoint 1, we successfully create a simple version to have room occupied with couple or non couple. We first create the new clusters and rooms. The rooms may be occupied by couple or non couple. If more than one female and male in the room, a chance of sexual activity may occured. This resulting in the occurrence of sexually transmitted infection (STI).

We shall include more working flow, especially on the intervention, treatment and prevention on our current model, so as to reflect more realistic conditions. This also serve as useful model to investigate the effect of different intervention.

In the program, simply run python main.py and the result will be a list of event that occurs in the simulated environment. We shall include a complete log file with statistics in our next checkpoint.

Parameters	Description
logfile	logfile name
room_cluster_count	number of cluster
room_per_cluster_count	number of room per cluster
prob_new_room_for_married	probability of the room as couple room
prob_new_single_male	probability of a new single male
max_age_male_resident	maximum age of male resident
max_age_female_resident	maximum age of female resident
std_probability	probability of having STI
mean_age_new_resident	the mean age of the new resident
sd_age_new_resident	standard deviation of the age of new resident
max_day_room_empty	maximum number the room is not occupied

Table 2: Description of parameters in the simulation

9 Simulation result

- we will have a table. then discussion about the result

10 Verification and Validation

10.1 Assumptions

- Only unprotected acts modeled in this analysis
- No age mixing input preference
- Partner notification is stratified by sex and age, however in the absence of data on changes in this prevention strategy, the parameters are kept time invariant
- Only heterosexual partnerships.
- Treatment ensued immediately following identification of infection, although this may not always happen in practice.

Furthermore, probability distribution of the parameters used in our model is shown in Table 10.1

Parameter/Variable	Description	Distribution
Population size	Population size for each age group	Uniformly distributed
Time step	Time step implemented in the model	A day
High risk	Fraction of the population defined as high risk	10% (Assumption)
Low risk	Fraction of the population defined as low risk	90% (Assumption)
	Testing symptomatic individuals	
Women	Testing of symptomatic women	1/(52*(0.079+0.072*Beta(4,4)))
Men	Testing of symptomatic men	1/(52*(0.079+0.072*Beta(4,4)))
	Casual partners	
High risk(HR)	Single, 65-79 HR	Beta(3,60)
	Single, 80-95 HR	Beta(3,400)
Low risk(LR)	Single, 65-79 LR	Beta(1,160)
	Single, 80-95 LR	Beta(1,160)
	Among paired	
High risk(HR)	Single, 65-79 HR	Beta(10,70)
Low risk(LR)	Single, 80-95 LR	Beta(10,100)
	Transmission	
Transmission probability	Per act probability	Beta(5.5, 50)))
With condom protection	condom effect parameter estimate is 1.6	$\text{Beta}(5.5, 50)^{1.6}$
	Natural recovery	
Women		1/(52*(1.13+0.5*Beta(4,4.969)))
Men		1/(52*(1.13+0.5*Beta(4,4.969)))
	Treatment Success	
Efficiency of antibiotics		Beta(190,8)))
	Partner Notification	
Women	Age65-79	Beta(4,3)
	Age80-95	Beta(4,3)
Men	Age65-79	Beta(4,3)
	Age80-95	Beta(4,3)
	Condom Use	
Casual partners	Weighted prevalence	0.131
Paired	Weighted prevalence	0.368

Table 3: Description of parameters governing testing, natural recovery and transmission probability

What are the model used (cite all the paper) Compare with the result

10.2 Limitation of the model

Some of the limitatio of our model: Interaction of the factor could be more complicated .... etc (just briefly talk about it, then talk about improvement)

11 Conclusion

In this discrete event simulation event, we have successfully implement a simulation of the STD event in a housecare.

12 Division of Labor

Task	Member
Data collection	All
Programming	D.Aaron Hillegass, Siawpeng Er
Literature review	Xiaotong Mu, Aiswarya Bhagavatula
Verification / Validation of Model	Siawpeng Er, Xiaotong Mu
Final Report	All

Task	Duration
Data collection	2 weeks
Modeling design and implementaion	4 weeks
Modeling revised	4 weeks

References

[1] Catharina P. B. Van der Ploeg, Carina Van Vliet, Sake J. De Vlas, Jeckoniah O. Ndinya-Achola, Lieve Fransen, Gerrit J. Van Oortmarssen, and J. Dik F. Habbema. Stdsim: A microsimulation model for decision support in std control. *Interfaces*, 28(3):84–100, 1998.

[2] K. Dietz and K. P. Hadeler. Epidemiological models for sexually transmitted diseases. *Journal of Mathematical Biology*, 26(1):1–25, 1988.

[3] Eva A. Enns and Margaret L. Brandeau. Inferring model parameters in network-based disease simulation. *Health Care Management Science*, 14(2):174–188, 6 2011.

[4] Neil M. Ferguson and Geoffrey P. Garnett. More realistic models of sexually transmitted disease transmission dynamics. *Sexually Transmitted Diseases*, 27(10):600–609, 2000.

[5] Janneke C.m. Heijne, Christian L. Althaus, Sereina A. Herzog, Mirjam Kretzschmar, and Nicola Low. The role of reinfection and partner notification in the efficacy of chlamydia screening programs. *The Journal of Infectious Diseases*, 203(3):372–377, Jan 2011.

[6] Sarah Kok, Alexander R. Rutherford, Reka Gustafson, Rolando Barrios, Julio S. G. Montaner, Krisztina Vasarhelyi, and on behalf of the Vancouver HIV Testing Program Modelling Group. Optimizing an hiv testing program using a system dynamics model of the continuum of care. *Health Care Management Science*, 18(3):334–362, Sep 2015.

[7] Reda Lebcir, Eren Demir, Raheelah Ahmad, Christos Vasilakis, and David Southern. A discrete event simulation model to evaluate the use of community services in the treatment of patients with parkinson's disease in the united kingdom. *BMC Health Services Research*, 17(1):50, 2017.

[8] Derrick Y. McDaniel. Sex and seniors - stds a new reality for the elderly, Apr 2017. `https://www.huffpost.com/entry/sex-and-seniors-stds-a-ne_b_9619778?`

[9] Kimberly A Powers, Azra C Ghani, William C Miller, Irving F Hoffman, Audrey E Pettifor, Gift Kamanga, Francis Ea Martinson, and Myron S Cohen. The role of acute and early hiv infection in the spread of hiv and implications for transmission prevention strategies in lilongwe, malawi: a modelling study. *The Lancet*, 378(9787):256–268, 2011.

[10] Minttu M Rönn, Ashleigh R Tuite, Nicolas A Menzies, Emory E Wolf, Thomas L Gift, Harrell W Chesson, Elizabeth Torrone, Andrés Berruti, Emanuele Mazzola, Kara Galer, and et al. The impact of screening and partner notification on chlamydia prevalence and numbers of infections averted in the united states, 2000–2015: Evaluation of epidemiologic trends using a pair-formation transmission model. *American Journal of Epidemiology*, 188(3):545–554, Apr 2019.

[11] Maria Xiridou, Ronald Geskus, John De Wit, Roel Coutinho, and Mirjam Kretzschmar. The contribution of steady and casual partnerships to the incidence of hiv infection among homosexual men in amsterdam. *Aids*, 17(7):1029–1038, 2003.

[12] Xiange Zhang. Application of discrete event simulation in health care: a systematic review. *BMC Health Services Research*, 18(1):687, 2018.

[13] Yu-Xuan Zhang, Johanna Barry, David Moore, and Sygal Amitay. Zhang et al 2012 plos one, 01 2013.