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Abstract

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Epidemic modeling is an important problem which

would be sampling a statistically significant percentage of the population, similar to an online data-collection portal, whereby information would be uploaded on a voluntary basis. Realistic collection of data from this lat-

Each of these simulation aspects (*where, who, when)* can be extended to include a multitude of cities, weakly coupled by institutions such as planes, trains, automobiles and buses supporting agent movement. In addition,

the simulation takes place. This area is defined by an image file incorporating institutions and homes, and is denoted by different colours in the input image (see Figure 2 for an example of a topology map simulating the City of Winnipeg). The central point of the simulation is an agent. An **Age** represents a person within the simulation.

- An agent is within walking distance of the destination institution.

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methods of inoculations or epidemiological management policies (e.g., restrictions on movement) have in the circumvention of an outbreak event. This will allow for epidemiologists to partially “close the loop” when evaluating policy. Using extensions such as those discussed above, a simulation can be run emulating a mutation. Figure 8 clearly illustrates this type of situation.

This observation brings up another aspect for consideration. In addition to disease spread and modeling, we might be able to model the effectiveness of timely vaccination and/or inoculations. Typically, vaccination clinics

of disease spread will have to be adjusted accordingly to incorporate their effects.

symptoms, and reduce the amount of time an individual may be infectious. Some are known to have an effect on type 'A' and type 'B' influenza-causing viruses. Tamiflu and Relenza are two such medications that belong to a separate class of medicines called neuraminidase inhibitors [13]. They work by stopping the particles of the virus from being released into human cells, hence limiting the *in vivo* spread of the infection. It is not know precisely how effective these kinds of anti-viral medications really are, but nevertheless, with widespread adoption, it is likely that models

Second, the current model schedules as weekdays and weekends. Although most people in the paid

areas known for student housing, e.g. Wolseley or granola-type areas of Winnipeg). Census data will be able to refine this.

Also, at present, in the defining of a car, the infection probability is considered to be zero. This statement assumes a single rider - and discounts the soccer mom phenomenon - again indirectly related to the unpaid work economy as well as leisure schedules.

Having acknowledged some of these more obvious limitations, the next sub-sections lend themselves to a discussion of more extensive modifications and data-mining opportunities. Our emphasis is on data mining of topological structures (networks) and the utilization of patterns of behavior as the cornerstones of the simulation effort. The following will also outline data-mining opportunities of an often less-than-obvious nature that may have a significant effect on epidemic modeling.

will serve as a means of extending the DSSW simulator to model interactions among a variety of cities with any number of participants. In its initial manifestation, it is really a cluster-based implementation of our agent-based epidemic model. In a cluster, each node would run an instance of a city and communication would emulate people traveling via air or train. Our packets in the TCP/IP sense would transport agents as their payload. We have started an EPI@home Google site and have just taken epi-at-home.com as a starting point to further disseminate the research which will be an open source grass roots initiative.

Means of extracting patterns of behavior could be taken from tracking technologies that are already in place - albeit not mined or exploited to the best of our knowledge - for generating behaviors that could be used in epidemic modeling.

These include financial transactions and cell-phone location technologies. Briefly, financial transaction tracking is widely deployed as a means of detecting fraud where anomalous behavior is flagged when unusual purchase-behavior patterns are inferred. The techniques used are usually related to profiling and learning customer behavior and monitoring events to uncover indicators of anomalous or fraudulent behavior from a database. Profile behavior information would provide additional empirical input to the DSSW simulator when combined with other demographical data where available. Of course, this would again be statistical in nature, providing a sample of patterns that could be used to augment modeled behaviors. The information mined, however, would not be the more difficult problem of determining anomalies, but rather the behavior profile itself. Most people, however, are particularly uncomfortable with this level of intrusion (more to do with perception than anything concrete) and data of this type are likely difficult to obtain without the involvement of the financial institutions themselves. Bio-surveillance centers do monitor for financial transactions such as prescription and over-the-counter medication (e.g., anti-diarrheals, anti-nauseals) purchases at pharmacies that are used as inputs to analysis tools that attempt to predict the potential outbreak of a disease. To some degree, this is already being done, whether people are aware or not.

The cell-phone industry has long been aware of "where" mobiles are, such that they can route calls as users move within a city or region. In addition, a number of new features are being added that enhance cellular location based services. These include E-911 as well as "where are you" services. Many newer cell phones will be or are already equipped with GPS, that allow greater location accuracy. In some cases, these technologies will and are being used in conjunction with the telecom service provider to deliver location-based services. For our purposes, only a statistical sample is required, as behavior patterns of others can be modeled around these samplings of baseline behaviors. In an extended services capacity, cell-phone tracking data would provide input to where people are and their patterns of movement. Clearly, this information exists (and is incorporated in some telecom client services) but would not likely be publicly available on a mass populous scale and certainly not unless sanitized. There are hash functions that can provide electronic "fingerprints" of users without actually revealing the identity of the user if this type of data were to become available. We plan on emulating this type of behavior-capture within the DSSW simulator. Substantiating our claim that this type of data may become available, it is worthwhile to note that, in addition to consumer-location-based services, there are a growing number of patents whereby data from cellular providers would augment a city's traffic light control system with dynamic traffic information. Clearly, if these systems are to be employed, issues such as privacy (Privacy Legislation) will be of paramount importance.

of people may arrive, but immediately transit through to other destinations). Thus, Las Vegas offers a different kind of opportunity for a disease to propagate than a majority of cities. It is possible to mine air traffic schedules to get a very reasonable flow in and out of Las Vegas. There are a defined number of hotels, all mineable from Google Maps or equivalent. In addition, a significant percentage of persons in Las Vegas work in the service industry. The most promising airline mining being considered as a first phase will be from add-ons such as those at Yapta's [17] or Flightaware's [18] flight-tracking website Although initially designed for providing a consumer with flight information, these can also be mined and provide empirical data for an epidemic simulator.

3) In any city, mining behaviour through scheduled public transport is a good way to model contracting a disease. Public transit systems transport people in high volume and high densities. Estimating ridership would likely be a challenge, but could be made available if the efficacy of the modeling could be demonstrated. An immediate goal of the DSSW for the Winnipeg model is to incorporate public transi

Furthermore, publicly available and electronic (wired and wireless) device-enabled Kiosks and vending machines are becoming more mait(re)1-1.5amd an areai

subway, etc. Some of this work is being done to provide behavior patterns that would be a factor in a bioterrorism attack and its impact. However, it is the mention of

no doubt be able to provide at least coarse estimates of spatial behavior patterns extracted from similar web services such the ema9999961(t48(-)]TJ1.39987.1(ema999us61(t(ge39987.1(ema999men99998(r)-298tion3999298(d)-293.60081961(er8.3h

tagged syringes (even when hidden from view), making them much easier for one to locate for proper and safe disposal. It should be noted that the needles would be tracked with a secure ID/database, whereas individuals

predisposition on the part of the virus as to who it infects. While we were motivated in this work to adapt our simulator to diseases such as HIV/AIDS, that problem is considerably more difficult to model as it involves greater complexity of behavior on the part of the agent. Part two highlights a list of limitations, extensions and research opportunities and provides a sampling of technologies that may have benefit in extracting or mining behavior from somewhat non-obvious or disparate sources. The final section of the paper outlines an approach where an agent-based model such as DSSW could be used to model a limited and constrained HIV/AIDS epidemic or outbreak. Through this paper we also hope we have brought opportunities and technologies to the attention of epidemic modelers that are perhaps more closely aligned to an engineer. Conversely, we hope we have brought opportunities in epidemic modeling to the attention of engineers.

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