Lecture Notes: Social Networks: Models, Algorithms, and Applications
Lecture 1: Mar 29, 2012
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1 Plan for today

Four papers were picked up for some empirical studies for today.

- Strategies for containing an emerging influenza pandemic in South East Asia. [1]
- Modelling targeted layered containment of an influenza pandemic in the United States. [2]

2 Strategies for containing an emerging influenza pandemic in South East Asia.

Abstract:
Highly pathogenic H5N1 influenza A viruses are now endemic in avian populations in Southeast Asia, and human cases continue to accumulate. Although currently incapable of sustained human-to-human transmission, H5N1 represents a serious pandemic threat owing to the risk of a mutation or reassortment generating a virus with increased transmissibility. Identifying public health interventions that might be able to halt a pandemic in its earliest stages is therefore a priority.

The basic reproduction number, R_0, quantifies the transmissibility of any pathogen, which is defined as the average number of secondary cases generated by a typical primary case in an entirely susceptible population. A disease can spread if $R_0 > 1$, but if $R_0 < 1$, chains of transmission will inevitably die out. Hence, the goal of control policies is to reduce R_0 to below 1.

Strategies to reduce R_0 at the source:

- Reduce contacts between individuals - social distance.
  - Quarantine.
  - School closure.
- Reduce susceptibility.
  - Usually is done by antiviral prophylaxis. [1] [2]
  - Vaccination.

[1] Giving drugs preventively. Targeted.
[2] Note that people do not often accept prescribed drugs.

Thailand model:

They modelled pandemic spread in South East Asia, as this region remains the focus of the ongoing avian H5N1 epidemic and is where most human cases have occurred. Data availability led them to model Thailand rather than any perceived greater risk of emergence compared to other countries in the region; however, they believe their conclusions are also valid for other parts of South East Asia. Surrounding countries like Myanmar, Laos, Cambodia do not have available enough data to perceive the study.

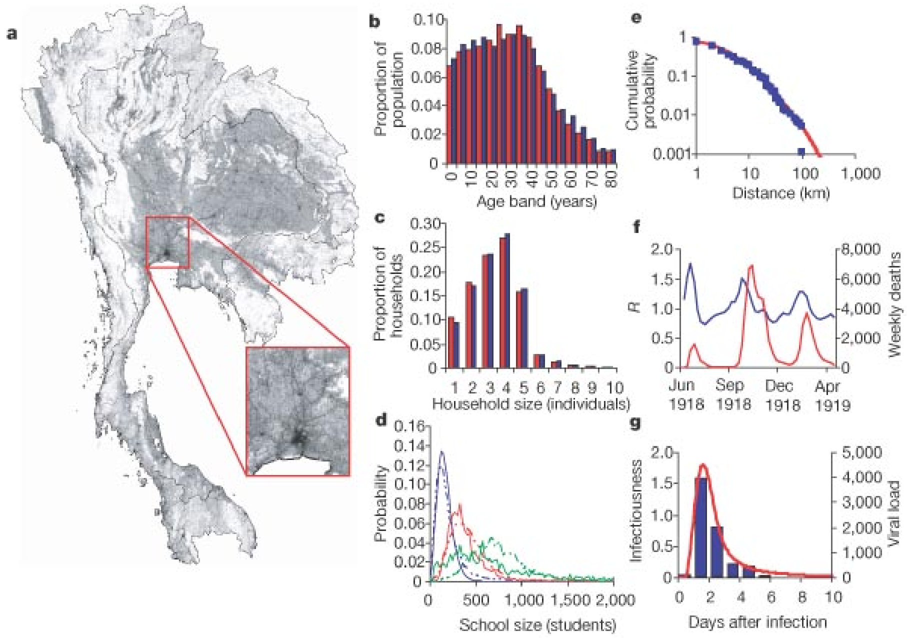
Available data:

- LandScan Data from Oak Ridge National Laboratory.[3]
- Demographics data.
- Census data.
- Travel data. Taken from a survey of 2517 residence.

In this research they have:

- Generated a household data using probabilistic distribution taken from the census data. Similar to generating a random graph with known degree distribution.
- Generated schools at random, based up on population distribution. School size data was modelled on sample of 24K school $\approx 60\%$ of schools in Thailand. Pupils were allocated to schools by distance.
- Using the same idea as above they have generated a workplace allocation.[3]
- Matched data on travel distances within Thailand with population distribution. Here they used data collected in the 1994 National Migration Survey on distances travelled to work to estimate movement kernel parameters.

[3] Thailand follows the power law distribution of workplace sizes.



a) Modelled population density of Thailand and 100-km contiguous zone of neighbouring countries, based on Landscan data and plotted on a logarithmic scale (light for low density, dark for high density). Inset shows Bangkok in more detail.
b) Age distribution of Thai population in 2003 in 5-yr bands (blue), and the corresponding age distribution of the simulated population (red).
c) As b but showing distribution of household sizes.
d) Observed (solid lines) and modelled (dashed lines) distributions of school sizes (blue, elementary; green, secondary; red, mixed).
e) Probability of travelling over a certain distance to work, estimated from data (blue) and from the simulated population (red). f, Weekly excess influenza-related mortality in 19181919 in Great Britain (red), and corresponding estimates of the reproduction number R (blue), calculated assuming $T_g = 2.6$.
g) Viral shedding data for experimental influenza infection (expressed in tissue culture infective doses (TCID50) per ml of nasal lavage fluid) compared with the modelled profile of infectiousness over time.

Infection model:
At the beginning of the simulation they have randomly assigned people to their places. So, every person has a home, work and school chosen uniformly at random. At the each time step[4] the person is infected with probability that is computed as a sum of contributions from infected individuals in the persons set of locations.[5] They fit parameters from previous pandemics and set parameters sort of "backwards" from R_0 and used R_0 values from previous pandemics.[6].

[4] Simulation step is a day.
[5] This is weighted.
[6] R_0 ranges from 1.6 to 1.8

Results:
A key conclusion is the need for multiple approaches: simple socially targeted prophylaxis is unlikely to be sufficient if the emergent virus has transmissibility levels near those of previous pandemic viruses. Geographically targeted policies are needed to achieve high levels of containment, with area quarantine being particularly effective at boosting policy effectiveness. The only scenario under which purely socially targeted strategies might be sufficient would be if viral transmissibility evolved incrementally and the emergent virus initially had an R_0 only slightly above 1

3 Modelling targeted layered containment of an influenza pandemic in the United States.

Abstract:
Planning a response to an outbreak of a pandemic strain of influenza is a high public health priority. Three research groups using different individual-based, stochastic simulation models have examined the consequences of intervention strategies chosen in consultation with U.S. public health workers. The first goal is to simulate the effectiveness of a set of potentially feasible intervention strategies. Combinations called targeted layered containment (TLC) of influenza antiviral treatment and prophylaxis and nonpharmaceutical interventions of quarantine, isolation, school closure, community social distancing, and workplace social distancing are considered. The second goal is to examine the robustness of the results to model assumptions. The comparisons focus on a pandemic outbreak in a population similar to that of Chicago, with 8.6 million people. The simulations suggest that at the expected transmissibility of a pandemic strain, timely implementation of a combination of targeted household antiviral prophylaxis, and social distancing measures could substantially lower the illness attack rate before a highly efficacious vaccine could become available. Timely initiation of measures and school closure play important roles. Because of the current lack of data on which to base such models, further field research is recommended to learn more about the sources of transmission and the effectiveness of social distancing measures in reducing influenza transmission.

Research groups:
Research was done by 3 groups. One research group is a collaboration of investigators at the University of Washington and Fred Hutchinson Cancer Research Center in Seattle and the Los Alamos National Laboratories (UW/LANL). One group is a collaboration of investigators at Imperial College and the University of Pittsburgh (Imperial/Pitt). The third group is at the Virginia Bioinformatics Institute of the Virginia Polytechnical Institute and State University (VBI).

Intervention Options:
They considered a set of interventions consisting of antiviral treatment and household isolation of identified cases, prophylaxis and quarantine of their household contacts, closure of schools, social distancing in the workplace, and social distancing in the community at large. Because these interventions are combinations of targeted and general interventions, they call them targeted-layered containment (TLC) approaches. They examined different levels of ascertainment of symptomatic

influenza cases, compliance with the interventions, and cumulative illness attack rate thresholds for initiating interventions.

Ascertainment of Cases:
Ascertainment of cases is key for targeted interventions, especially the use of influenza antivirals, case isolation, and quarantine of contacts. Rapid, specific diagnosis will be important. They assumed that only 67% percent of influenza infections are symptomatic. They considered two levels of ascertainment of symptomatic influenza cases, namely, 60% and 80%. They assume no asymptomatic influenza infections are ascertained. These levels of ascertainment and pathogenicity correspond to ascertaining 40% and 54% of influenza infections. Interventions within the households of ascertained cases include the following:

- Treatment of ascertained cases. All ascertained cases are treated with one course of antiviral drug for 5 days beginning one day after the onset of symptoms. In the UW/LANL model, 5% of treated cases stop taking the drug after 1 day.
- Targeted antiviral prophylaxis (TAP) of household contacts. All household contacts receive one course (10 days) of prophylaxis beginning 1 day after the onset of symptoms of the index case. In the UW/LANL model, 5% of individuals who receive prophylaxis stop taking drug after 2 days.
- Home isolation of cases. Ascertained cases are isolated in the home, but not isolated from the people with whom they live, with a compliance rate of 60% or 9%.
- Quarantine of household contacts. Household contacts of ascertained cases are quarantined within the home for 10 days with a compliance rate of 30%, 60%, or 90%.

Results: Table 2 and Fig. 1 show the results. Increasing attack rates correspond to higher R_0 values. In the absence of intervention, the three models produce similar illness attack rates, in the range 42.4 46.8% at an R_0 of 1.9 (2.1), increasing to the range 56.5 58.8% at an R_0 of 3.0. At the lowest R_0, in all three models, all five baseline intervention scenarios are effective at reducing the illness attack rates.

Figure 1:

Table 2. Illness attack rates (%) and (antiviral courses per 1,000) using scenarios described in Table 1 in the Chicago population

Scenario% compliance/ ascertainment	Intervention threshold, %	R_0 = 1.9 (2.1)			R_0 = 2.4			R_0 = 3.0		
		Imperial	UW	VBI	Imperial	UW	VBI	Imperial	UW	VBI
1	NA	42.4 (0)	46.8 (0)	44.7 (0)	52.4 (0)	52.4 (0)	51.1 (0)	58.8 (0)	58.8 (0)	56.5 (0)
2 30/60	1	7.3 (104)	2.8 (38)	3.9 (59.1)	15.5 (239)	4.1 (61.2)	9.7 (140.4)	27.4 (421)	8.5 (138.4)	20.1 (275.1)
3 60/60	0.1	1.1 (17.9)	0.31 (4.3)	1.3 (29.7)	4.1 (69.8)	0.41 (6.2)	3.2 (70.6)	18.1 (300)	1.03 (17.1)	9.4 (189)
4 60/80	0.01	0.22 (4.6)	0.04 0.76)	0.10 (3.2)	0.66 (14.2)	0.05 (1.1)	1.4 (41.7)	10.1 (210)	0.12 (2.5)	3.8 (105.9)
5 90/60	0.1	0.17 (3.2)	0.30 (4.1)	1.2 (28.8)	0.66 (14.2)	0.30 (5.8)	2.7 (59.4)	11.5 (192)	0.86 (14.2)	6.4 (132.2)
6 90/80	0.01	0.20 (4.2)	0.04 (0.76)	0.07 (2.3)	0.54 (9.4)	0.05 (1.0)	1.2 (35.5)	5.4 (112)	0.11 (2.1)	2.8 (80.2)

The Imperial/Pitt model results are based on an average of 10 realizations, the UW/LANL results on an average of 5 realizations, and the VBI results mostly on one realization.

Figure 2:
Influenza illness attack rates for three R_0 values without intervention and with five scenarios of TLC intervention by using the three different models (Chicago population). The R_0 values of 1.9 and 2.1 are considered as a single comparison.

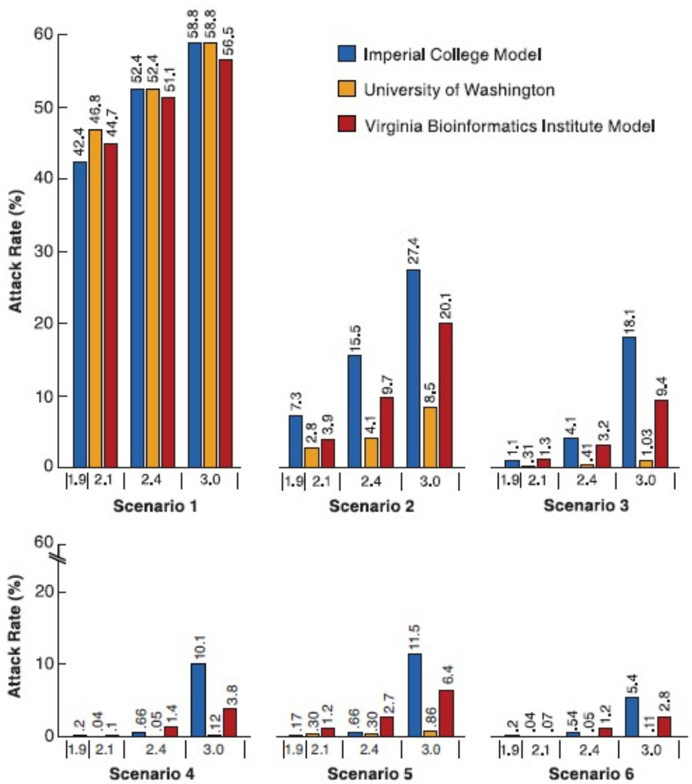


Figure 3:

Table 3. Percentage of infections by place and scenario, R_0 = 1.9 (2.1) in the Chicago population

	Scenario 1. No intervention			Scenario 2			Scenario 3		
	Imperial	UW	VBI	Imperial	UW	VBI	Imperial	UW	VBI
Illness attack rates	42.4	46.8	44.7	7.3	2.8	3.9	1.1	0.31	1.3
Places									
Home	33.1	39.4	41.1	48.3	58	45.9	50.4	59	36.9
Work	21.8	14.5	28.6	12.9	10	27.8	13.5	10	18.7
School	16.0	18.8	23.3	11.7	11	9.6	9.0	11	2.7
Day care	–	1.1	–	–	0	–	–	0	–
Play group	–	0.8	–	–	0	–	–	0	–
College	–	–	3.3	–	–	12.3	–	–	40.0
Shopping	–	–	2.0	–	–	2.4	–	–	1.0
Neighborhood	–	17.7	–	–	15	–	–	15	–
Neighborhood clusters	–	7.7	–	–	5	–	–	4	–
Other/Community	29.0	0	1.7	26.6	0	2.0	23.8	0	0.8
Totals									
Primary Groups*	70.9	72.7	93.0	72.9	79	83.3	72.9	79	58.3
Community†	29.0	25.4	3.7	26.6	20	4.4	23.8	19	1.8

*Includes home, school, workplace, and for the UW/LANL model, day care and play groups.
†Includes groups subject to community social distancing.

Conclusion: Using three different models, we have examined targeted layered containment strategies based on social distancing, rapid case ascertainment, and targeted prophylaxis that, in theory, might be effective in reducing transmission of pandemic influenza. Timely intervention reduces the final number of influenza illnesses. Especially at values of $R_0 \approx 2$ or below, the more probable values for a pandemic strain, the interventions are similarly, although not identically, effective in all three models. At the lower R_0, all three models show considerable effectiveness of the suite of NPIs[7]. School closure plays an important role in all three models.

References

[1] N. Ferguson. *Strategies for containing an emerging influenza pandemic in South East Asia.* 2005: Nature, 437, 7056: 209.

[2] N. Ferguson. *Modelling targeted layered containment of an influenza pandemic in the United States.* 2007:

[3] Oak Ridge National Laboratory - *http://www.ornl.gov*

[7] nonpharmaceutical interventions.