



University
of Manitoba

Agent-based models

MATH 8xyz – Lecture 26

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The University of Manitoba campuses are located on original lands of Anishinaabeg, Ininew, Anisininew, Dakota and Dene peoples, and on the National Homeland of the Red River Métis.

We respect the Treaties that were made on these territories, we acknowledge the harms and mistakes of the past, and we dedicate ourselves to move forward in partnership with Indigenous communities in a spirit of Reconciliation and collaboration.

Outline

What are agent-based models (ABM)

When to use ABM

When not to use ABM

Some examples

Antibiotic resistance in hospitals

Effectiveness of contact tracing

Contacts during Hajj

What are agent-based models (ABM)

- ▶ Early in the life of these models, they were called IBM (individual-based models) ▶ Over the years, a "philosophical" distinction has emerged:
 - ▶ IBM are mathematical models that consider individuals as the units; e.g., DTMC, CTMC, branching processes, etc.
 - ▶ ABM are computational models whose study is, for the most part, only possible numerically

ABM vs Network models

- ▶ Network models endow vertices with simple systems and couple them through graphs
- ▶ Can be ABM, but some networks can also be studied analytically ▶ Not enough time to go into this, a very interesting subject!

When to use ABM

► ABM are very useful to decipher contact processes ► Classic mathematical models capture contact by using approximations of what contact could be like ► Classic models allow some flexibility (see section about incidence functions in Lecture 02) but they remain limited ► ABM can model actual trajectories of individuals, so given a definition of what a contact is (how close do you need to be for a contact to take place), can count them efficaciously

ABM are very useful to understand behavioural responses

- ▶ ABM are very useful to understand behavioural responses

When not to use ABM

- ▶ As with all tools, beware!
- ▶ There is a law of large numbers effects happening often: if you have many units, unless some emergent behaviour arises, you get the same results using ODEs...

With this specific tool, beware!

- ▶ There is a certain tendency in CS people to create yet another system and seek adoption by users

Some examples

- ▶ Antibiotic resistance in hospitals
- ▶ Effectiveness of contact tracing
- ▶ Contacts during Hajj

Antibiotic resistance in hospitals

- ▶ D'Agata, Magal, Olivier, Ruand & Webb. Modeling antibiotic resistance in hospitals: The impact of minimizing treatment duration, Journal of Theoretical Biology (2007)

An IBM that's almost an ABM

- ▶ This work is a good illustration of the "cultural proximity" between IBM and ABM ▶ Model is stochastic and individual-based, in good enough form that approximating ODE can be derived ▶ Allows for very specific tracking of the status of individuals through the process (almost an ABM in this sense)

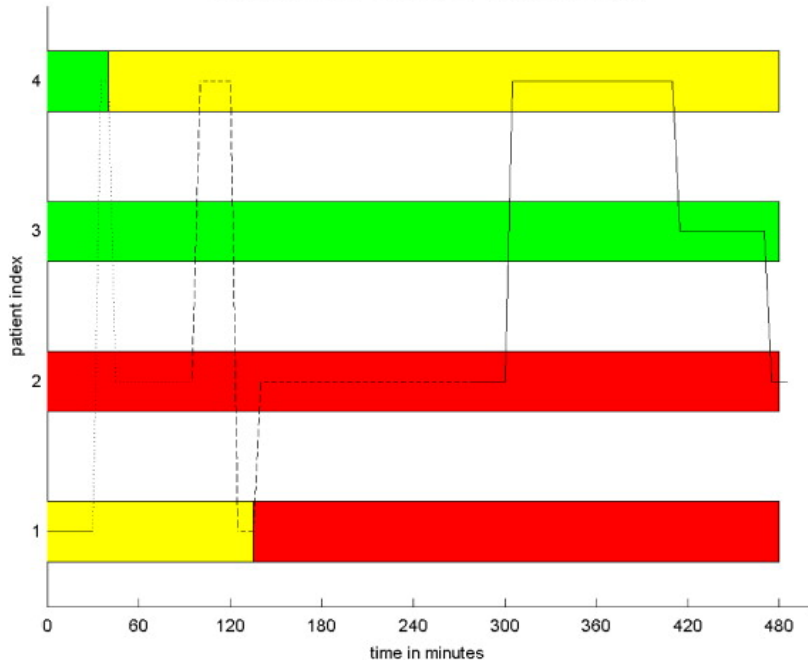
The setup

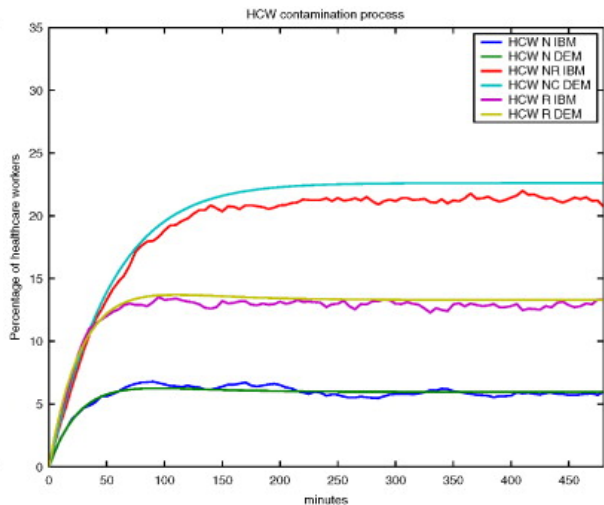
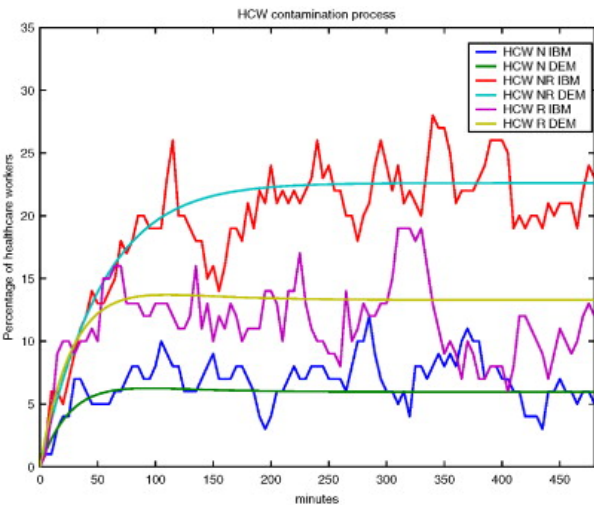
► Three processes:

1. admission and exit of patients
2. infection of patients by HCW (health care workers)
3. contamination of HCW by patients

► Contamination of HCW is "transient": they are carriers, if they wash their hands properly, they become OK ► Each day has 3 shifts of 8h for HCW ► Patients are put in contact by visits of HCW ► Rules for contaminations per unit time

AV=60, AC=60, PI=0.5, PC=0.5, Time step=5 minutes





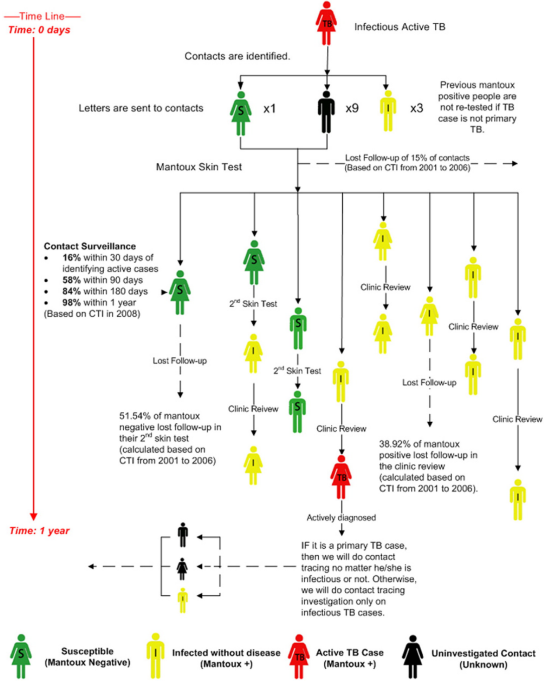
Effectiveness of contact tracing

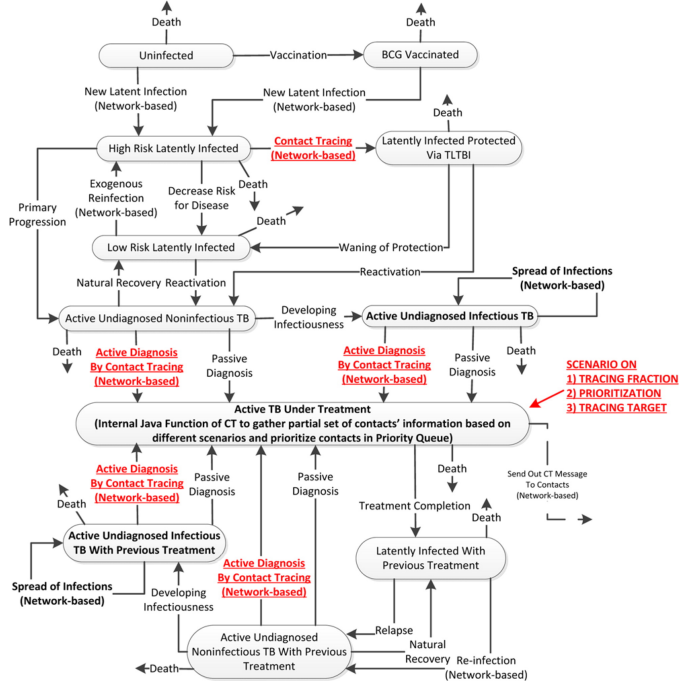
- ▶ Tian, Osgood, Al-Azem & Hoepfner. Evaluating the Effectiveness of Contact Tracing on Tuberculosis Outcomes in Saskatchewan Using Individual-Based Modeling, Health Education & Behavior (2013)

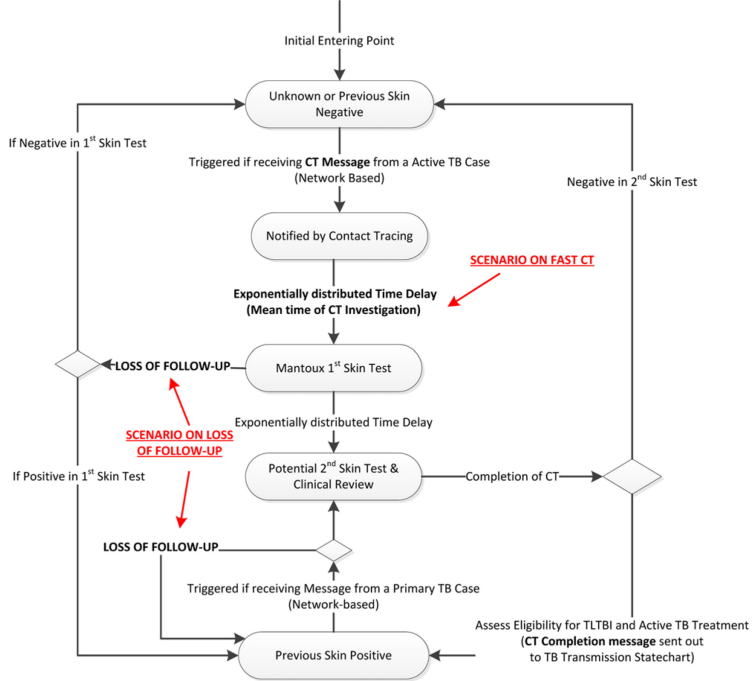
Evaluation of contact tracing in TB

- ▶ Evaluation of contact tracing in TB

Time Line
Time: 0 days





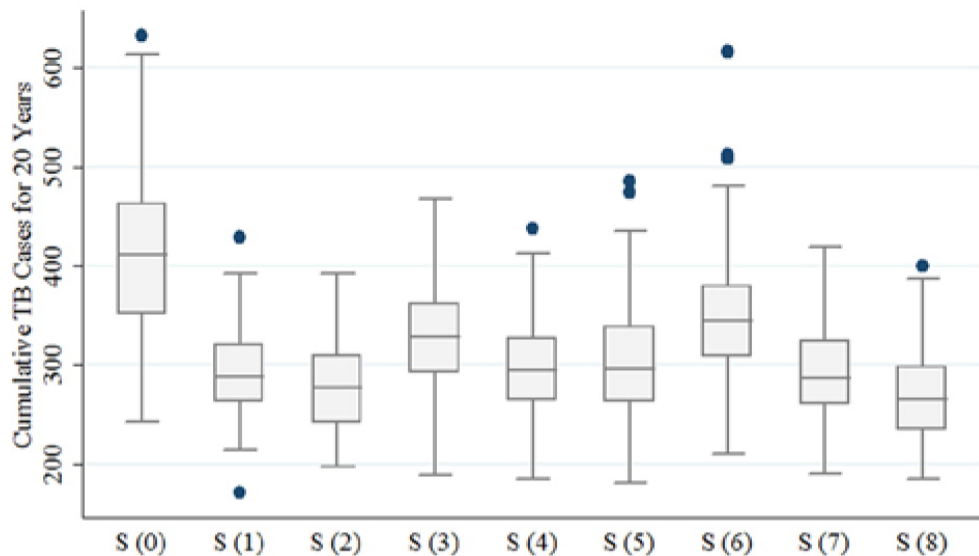


Scenarios

- ▶ They can then formulate scenarios Scenario illustration ▶ They then run these scenarios and compare results

Effect of Contact Tracing Investigation on Cumulative TB Cases

(N=100 Per Scenario)



Note: S(0) -- No Contact Tracing Investigation.

Contacts during Hajj

- Tofighi, Asgary, Tofighi, Najafabadi, Arino, Amiche, Rahman, McCarthy, Bragazzi, Thommes, Coudeville, Grunnill, Bourouiba and Wu. Estimating Social Contacts in Mass Gatherings for Disease Outbreak Prevention and Management (Case of Hajj Pilgrimage), Tropical Diseases, Travel Medicine and Vaccines

Contacts during Hajj

► In a mass gathering event like Hajj, lots of people come together originating from many countries ► If propagation occurs during the event, this has the capacity to spread infection far and wide when individuals (pilgrims here) return home ► Contacts during part of the event are really specific in their configuration

The setup

► Word of warning: I am quite fuzzy on the specifics :) ► Pilgrims enter Masjid al-Haram mosque through several gates ► Proceed to Mataaf (area around Kaaba), circle the Kaaba 7 times counterclockwise (process is the Tawaf) ► Then do seven trips between Safa and Marwah (process is the Sa'ee)

Tawaf in pre-COVID-19 times

- ▶ YouTube: Tawaf in pre-COVID-19 times

Tawaf - Socially distanced version

- ▶ YouTube: Tawaf - Socially distanced version

Sa'ee in pre-COVID-19 times

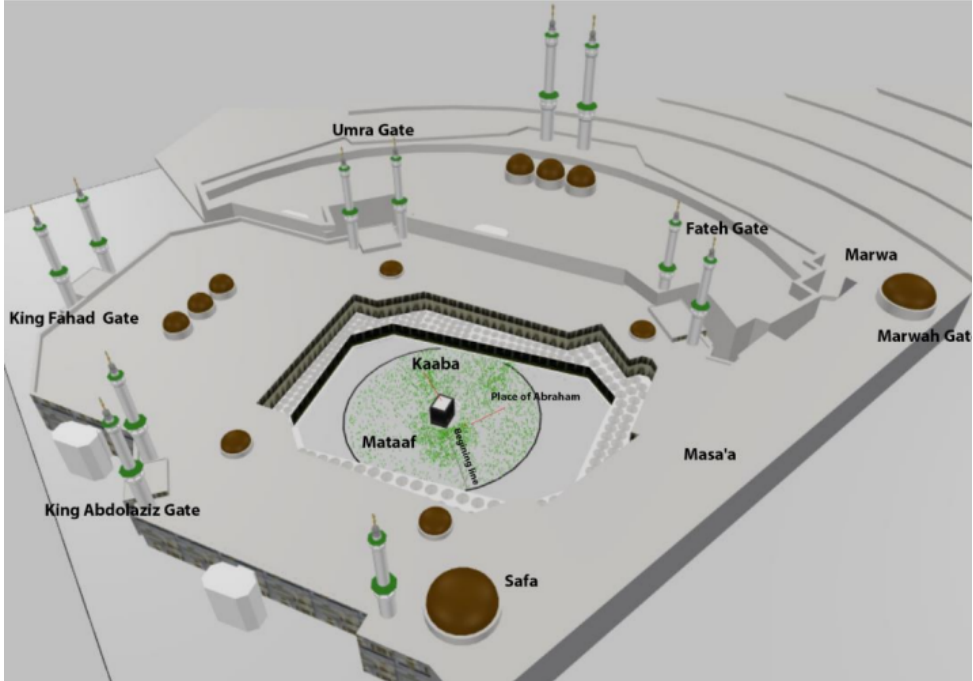
- ▶ YouTube: Sa'ee in pre-COVID-19 times

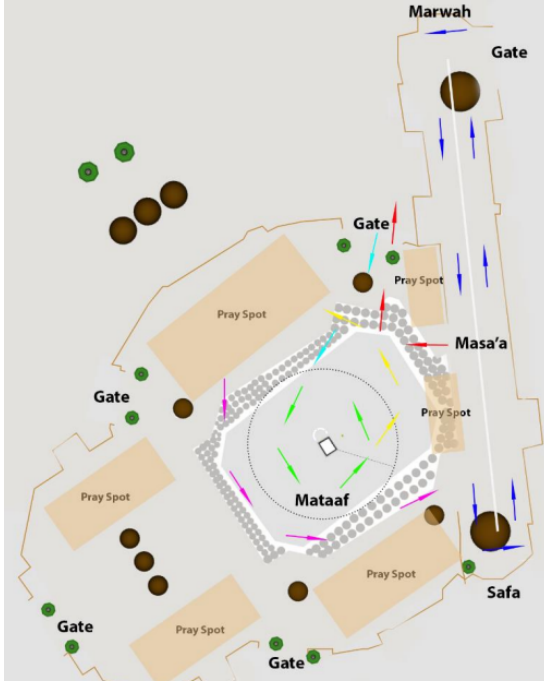
Sa'ee - Socially distanced version

- ▶ YouTube: Sa'ee - Socially distanced version

Crowd dynamics

- ▶ Typically high density crowds
- ▶ Very specific mixing patterns
- ▶ Opportunities for transmission are very high
- ▶ However, control mechanisms are also available
- ▶ Understanding contact patterns and frequency would help





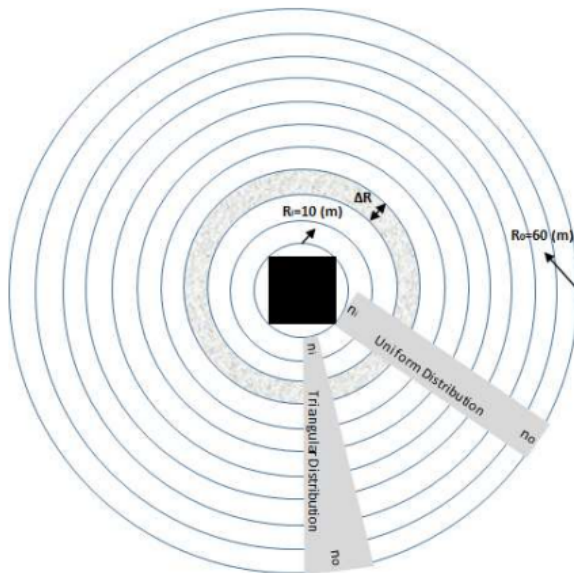


Figure 5. The general setting of Tawaf and pilgrim distribution in social distancing

Simulation video 1

► YouTube: Hajj simulation 1

Simulation video 2

► YouTube: Hajj simulation 2

Bibliography I