Infection Risk Score:

Identifying the risk of infection propagation based on human contact

1st ACM SIGSPATIAL International Workshop on Modeling and Understanding the Spread of COVID-19 (COVID-19 2020)

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Background

- Current practices to contain pandemic center around general guidelines
  - Social Distancing
  - Wearing masks
  - Contact tracing

- With things easing out in some countries, to reduce the risk of 2nd or 3rd wave, we need to efficiently manage spatial outbreak in different contexts, such as:
  - Indoor spaces[1] (offices, hospitals, hotels[2], etc.)
  - Services (delivery, etc.)
  - Social (local gatherings[4], visits of friends[3])

[1] H. Qian, et al. "*Indoor transmission of SARS-CoV-2*" medRxiv (2020).
[2] "*Hotel quarantine linked to 99% of Victoria's Covid cases, inquiry told*", The Guardian, 18th Aug 2020
[3] "*Home visits the biggest threat to Victoria's new normal*", 9News, 26th Oct 2020
[4] "*Kanpur: Covid-19 norms flouted in Dussehra festivities*", Times of India, 27th Oct 2020

Motivation: Current works and issues

- Current work can be categorized into
  - Survey based studies[5, 6]: People report on factors such as medical history, usage of PPE, etc.
  - IoT Based studies: Aarogya Setu[7], COVIDSafe[8] (survey[9])
  - Wearables – EasyBand[10]
  - Epidemic Modeling based[11]
- Issues with infection tracking innovations and advancements:
  - Disease may not show any symptoms for a long period (exposed state) or even no symptoms (Asymptotic cases)
  - The methods deployed are reactive not pro-active
    - List of infected patient is updated post the tests and isolation process
  - Infected people are typically isolated and not allowed to meet anyone. Thus, such apps cannot tell (for COVID-19 case) if you are exposed

[5] M. Mhango, et al., "COVID-19 Risk Factors Among Health Workers: A Rapid Review", Safety and Health at Work, 11, 3 (Sept. 2020), 262–265
[6] World Health Organization, "Health workers exposure risk assessment and management in the context of COVID-19 virus: interim guidance", 4 March 2020, Technical Report.
[7] https://www.mygov.in/aarogya-setu-app/
[8] https://www.health.gov.au/resources/apps-and-tools/covidsafe-app
[9] M. Islam, et al., "A Review on the Mobile Applications Developed for COVID-19: An Exploratory Analysis", IEEE Access, 8(Aug. 2020), 145601–145610
[10] M. Shukla, et al., "Privacy Guidelines for Contact Tracing Applications", arXiv (April 2020), 1–10
[11] M. Shahzamal, et al., "Airborne Disease Propagation on Large Scale Social Contact Networks", In 2nd IWSS (Pittsburgh, USA), ACM, 35–40.

Motivation: Questions

- Can management of infection spread be made more proactive?
- Can we estimate the risk of social situations and potential propagation?
- Can individuals and organisations be provided with inputs, based on which they can take early actions?

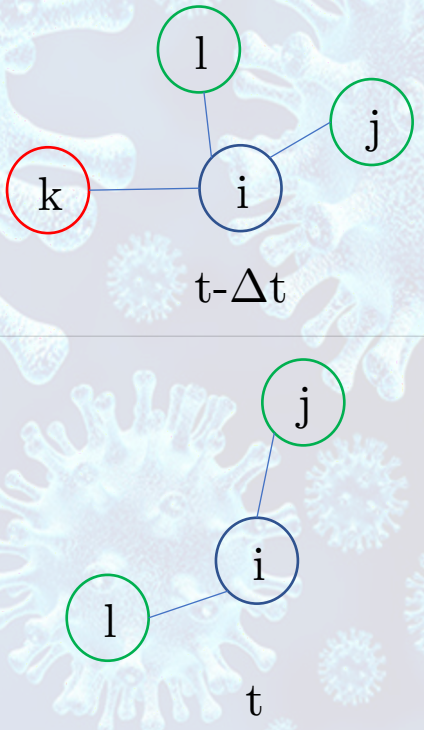
Contribution

- Infection risk score metric
  - Based on local neighborhood, transmission likelihood and vulnerability to a disease
- Evaluation using realistic dataset
  - Small scale school specific study
- Adaption of risk score using smartphones
  - Alpha version of the application available to test

Risk Score: Risk Propagation Model

- Based on local neighborhood, transmission likelihood and vulnerability to a disease

$$r_{i,t} = \frac{v_{i,t} \times r_{i,t-\Delta t} + \sum_{j \in N_{i,t}} w_{j,t} \times (E_{i,j,t} + r_{j,t-\Delta t})}{1 + \sum_{j \in N_{i,t}} w_{j,t}}$$



- Here
  - Exposure caused by a neighbor j ($E_{i,j,t}$) where

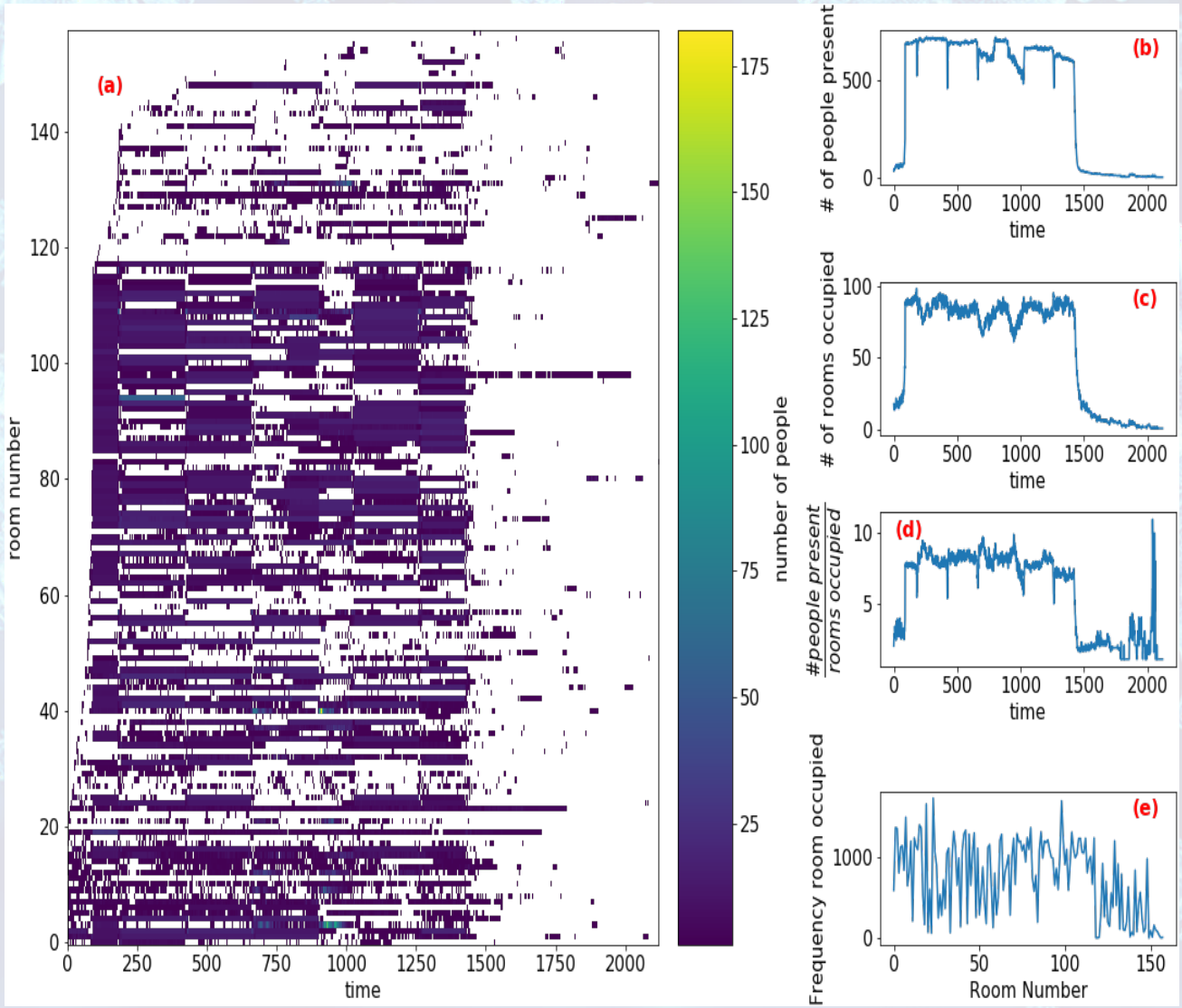
$$E_{i,j,t} = \Delta t \times n_{i,j,t}$$

    - $n_{i,j,t}$ is the number of pathogens released by j in vicinity of i
  - Neighbor weight ($w_{j,t}$) or the transmission likelihood
  - Node risk score ($r_{i,t-\Delta t}$) at time t-Δt
  - Self Vulnerability ($v_{i,t}$)
    - Such as in/out-door, age, etc.

Evaluation

- Lack of fine-grained mobility datasets for COVID-19. Best we found[12]
  - School data with 158 rooms, 789 people, 1 day data from 6am to 4:30 pm
    - Not uniform distribution
    - Only 62% rooms occupied
    - Some rooms always empty
- We let the epidemic happen using SIS epidemic model

$$\frac{dS_{i,t}}{dt} = -\frac{\beta S_{i,t} I_{i,t}}{N_{i,t}} + \gamma I_{i,t}$$
$$\frac{dI_{i,t}}{dt} = -\frac{dS_{i,t}}{dt}$$

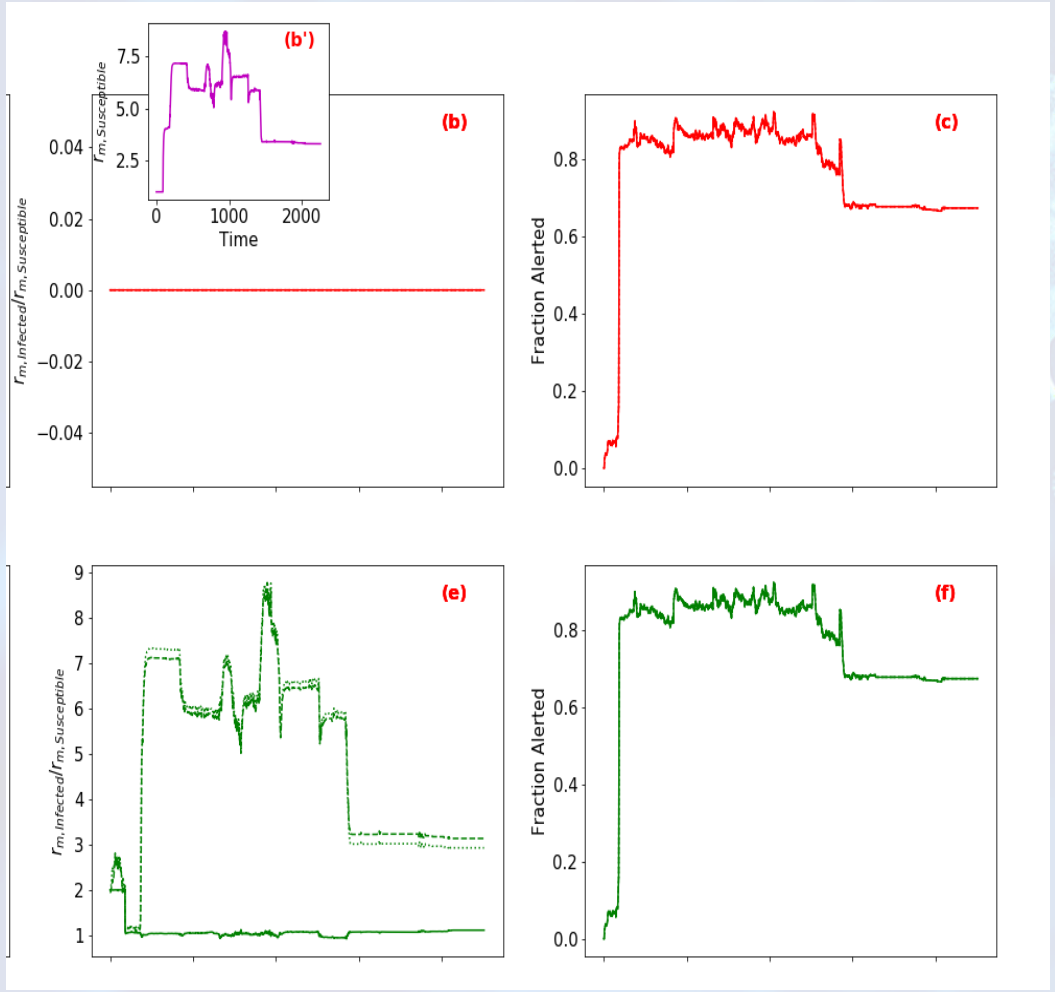


[12] M. Salathé, et al, "A high-resolution human contact network for infectious disease transmission", in Proceedings of the National Academy of Sciences 107, 51 (Dec. 2010), 22020–22025.

Results

**Assumptions:
- Weights are normally distributed
- Homogenous mixing

Initial infection = 0.00, $\boldsymbol{\beta} = \{0.0, 0.5, 1.0\}$, $\boldsymbol{\gamma} = 0.0$
Initial infection = 0.01, $\boldsymbol{\beta} = \{0.0, 0.5, 1.0\}$, $\boldsymbol{\gamma} = 0.0$



Initial infection = 0.00, $\boldsymbol{\beta} = \{0.0, 0.5, 1.0\}$, $\boldsymbol{\gamma} = 0.75$
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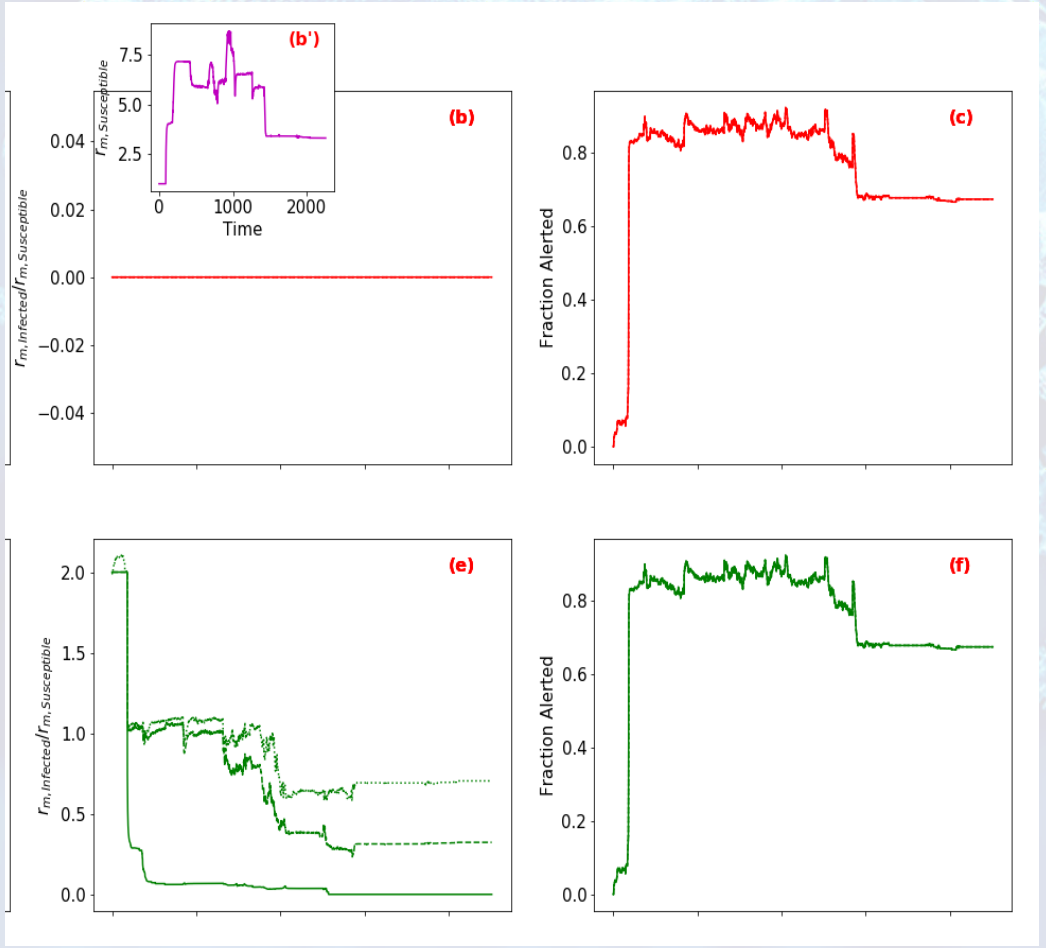
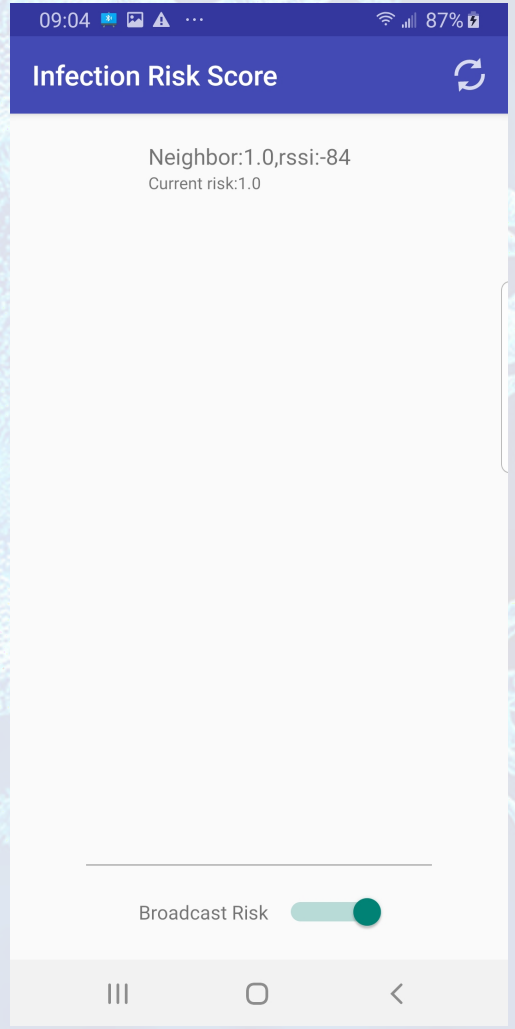


$$r_{i,t} = \frac{v_{i,t} \times r_{i,t-\Delta t} + \sum_{j \in N_{i,t}} w_{j,t} \times (E_{i,j,t} + r_{j,t-\Delta t})}{1 + \sum_{j \in N_{i,t}} w_{j,t}}$$

Risk Score implementation using Smartphone

- Individual risk scores are broadcasted using Bluetooth Low Energy (BLE)
- Each phone computes its instantaneous risk score based on smartphones in its neighborhood
- Does not require a centralized database and is privacy preserving since identity information is not broadcasted



0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
UUID																r	0	1	.	0	0	w	0	.	5	0					

BLE advertising packet format

Potential use cases and future directions

- Use cases and dissemination activity
  - Spatial region risk score as

$$r_t^{A_a} = \frac{\sum_{\forall i \in L_a} r_{i,t}}{||L_a||}$$

  - Regions could be defined at any spatial scale (building, city, etc.)
  - In talks with many organizations that showed interest in our application.

- Future direction
  - Increasing score accuracy
    - Incorporating more contextual information and quantify weights
    - Exposure context parameters
  - Increasing outreach activity

Conclusion

- We present risk score metric based that on local neighborhood, transmission likelihood and vulnerability to a disease
- Our prototype App based implementation of Risk Score can enforce social distancing where people are more cautious when meeting others.

- Limitations
  - Model: There is lack of fine-grained mobility datasets for COVID-19, making it difficult to use a purely data science/machine learning approach
  - Application: Usage but the risk model is independent of usage related issues.

Thank you

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https://rachit.gitlab.io

For testing application please contact us

Credits (Image Source):
Background: https://www.paho.org/en/news/25-3-2020-similarities-and-differences-covid-19-and-influenza
Kanpur: Covid-19 norms flouted in Dussehra festivities", Times of India, 27th Oct 2020