Understanding the Risk of COVID-19 Transmission on Trains

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Abstract

To understand the extent of the risk of the Covid-19 disease transmission among the train passengers, then there is a need for a formulation of an appropriate model that would adequately assess the risk of Covid-19 transmission. This work considered the passenger dynamic throughout their journey and explore how modelling approaches could be used to understand, thus mitigate possible transmission as passengers enter and leave a train.

Getting on the Train

Passengers motion towards the train carriage is model as in a fluid dynamics framework.

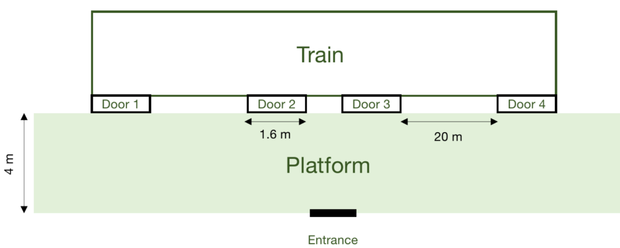

Figure 1. Train platform set-up

More precisely, we simulate density of passengers movement with the convection-diffusion PDE and the passengers waiting on a railway platform for a train are initially scattered.

$$\partial_t u + \nabla \cdot (\vec{v}u) = \nabla \cdot (\sigma \nabla u), \quad u \in C^1(\Omega)$$

u is the crowd density, $\vec{v}$ represents the velocity , σ is the diffusivity parameter. The initial domain Ω is represented by the platform in Fig 1.

Passengers Distribution

The passengers access to the platform from the midpoint of the bottom boundary and scatters as an exponential function.

$$u_0 = e^{-(\beta_1(x-0.5)^2+\beta_2(y-0.8)^2)},$$

where β_1 and β_2 characterise the level of initial spread.

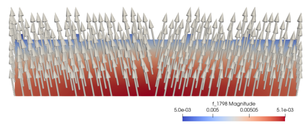

Figure 2. Velocity field for passengers.

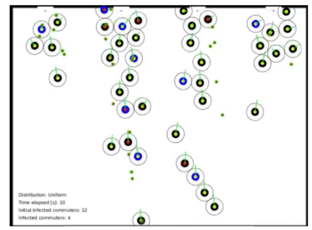

Figure 3. Passengers Movement.

Getting off the Train

- The queue has N passengers at location $X_n(t)$, $n = 0 \ldots N-1$..
- The queue move such that X_n exits before X_{n+1}.
- When $X_n = L$ then the n^{th} passenger will be assumed to have left the carriage with time Δ_n
- If proportion α of the passengers are infectious. The number of passengers encountered is then $\alpha(L - X_n(0))$.

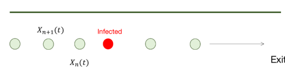

Figure 4. Queue at train door

Using velocity based model, with function f which describes the behaviour and distance between passengers.

$\dot{X}_{n+1} = f_{n+1}(X_n - X_{n+1}), f(r) = 0, r < d_1, f(r) = V, r > d_2.$

d_1, d_2 are social distance. Initially we will have everyone standing socially distant, $r > d_1$.

Simulation Result during Boarding

We compute the density of the passengers inside each door at each time step and see how it is affected by the parameter β_1, which controls the scattering of the passengers on the platform.

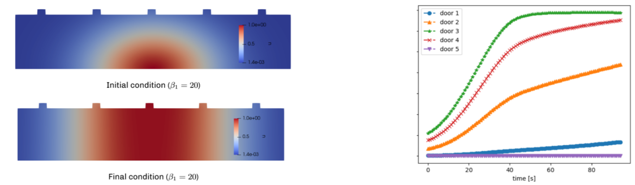

Figure 5. Density of passengers

Simulation Result for Departure

- A passenger has a waiting time before they can move.
- Takes a further travel time to leave the train.

Passenger	Waiting time (s)	Travel time (s)
1	0.45	6.04
2	0.90	10.3
3	3.45	14.2
4	6.67	18.3
5	9.24	22.4
6	12.3	26.0
7	15.3	30.1
8	17.8	34.6
9	20.8	39.0
10	23.9	42.5

Figure 6. Simulated time

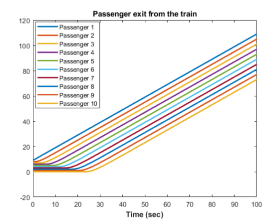

Figure 7. Simulated distance

Future Work

- Lifting passengers distribution restriction to simulate more realistic conditions.
- Exploring the simple viral load modelling of a queue system.
- Incorporating the equations of motion to better capture the characteristics of passenger population.

This work is funded by the Virtual Forum for Knowledge Exchange in the Mathematical Sciences (V-KEMS)

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