

Pedestrian behaviour modeling in Indian Context



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Abstract



Growing chaos in cities and towns calls for better management of public places. There is a need for scientific approach which can predict and model motion of pedestrians and their interactions with the surroundings. This interaction involves interaction with static objects such as walls, trees etc. and moving objects such as other pedestrians, vehicles etc.

Data Collection



- Videos were taken for controlled and uncontrolled scenarios
- Uncontrolled scenarios were videos taken during festivals and in shopping malls
- Computer Vision algorithms used to track trajectories of pedestrians from the videos
- Publicly available datasets were not used as they were not of an Indian scenario

Controlled experiments



Fig.03 (a) Single Walk



Fig.03 (c) Random Walk



Fig.03 (b) Head-on



Fig.03 (d) Bottleneck

Uncontrolled experiments



Academic Area, IIT Kanpur



Z-Square Mall, Kanpur

Pedestrian Detection and Tracking



- Videos were pre-processed by adjusting brightness and contrast
- Perspective correction was applied
- Background subtraction used to first locate target areas and noise removed by eroding and dilating
- SVM classifier is used to identify which of these areas is a human
- SIFT features of the human are used to track it across frames

Pedestrian Detection and Tracking



The circles show the automatically detected pedestrians

Modeling 'Social Force'



- Social Force is the force felt by a pedestrian which governs its motion
- This force primarily consists of three components -
 - Interaction Force - The repulsive force describing attempts to keep a certain safety distance from other pedestrians
 - Obstacle Force - The repulsive force describing attempts to keep a certain safety distance from obstacles
 - Driving Force - The force driving a pedestrian toward its desired goal

Interaction Force



- We consider two different models of interaction force -
 - Power Law model - Describes interaction force as a function of time to collision
 - Helbing's Elliptical Model - Describes interaction force as a function of the distance vector pointing between the pedestrians and the velocity of their approach
- The interaction forces obtained by the models above are a pairwise interaction force i.e. force between two pedestrians
- For a multiparticle case, to get the force experienced by a particle, we calculate this pairwise force between that particle and all its neighbours. Assuming the Law of Superposition to hold, we add up these forces to get the total force experienced by the particle
- Although in real scenario, the parameters of the interaction force models would differ from individual to individual, we assume a homogenous population i.e. same values for every individual, for simplicity
- When particles come in contact with each other, we simulate interaction force between them as an inelastic collision

Obstacle Force



- For obstacles such as walls, we calculate interaction force by Power Law model, assuming the wall to be made up of fixed pedestrians of infinite mass
- If a pedestrian comes in contact with an obstacle, its interaction force is modelled as an inelastic collision
- Obstacles have been used to simulate bottlenecks for a multiparticle system.
- For simplicity, assumed a zero force by an obstacle if a pedestrian is more than 3 particle diameters away from it

Driving Force



- This is the force responsible for the drift of pedestrians toward their goal
- Analogous to a potential difference responsible for drift of electrons in a particular direction
- The goal of a pedestrian can be categorised into two -
 - Direction Oriented - Desiring to reach a particular velocity
 - Goal Oriented - Desiring to reach a particular point
- Desired direction (e^0) - A unit vector pointing in the instantaneous direction that the particle has to go to reach its goal position or velocity. It is calculated by subtracting the goal position/velocity from the current position/velocity and normalising the result
- Desired speed (v^0) - The speed at which the pedestrian would walk if there are no other obstacles or pedestrians interacting with it
- Relaxation time (τ) - The time taken to go from rest to desired speed
- Force is given by $1/\tau * (v^0 e^0 - v)$

Helbing Circular Model



- This model assumes every particle to have a circular territory of radius r_i which they try to keep as away from other pedestrians as possible.
- Hence, the repulsive interaction force(f_{ij}) between two pedestrians i and j decreases exponentially with distance between their territories ($d_{ij}-(r_i+r_j)$)
- Thus, $f_{ij} = A_i \exp((d_{ij}-(r_i+r_j))/B_i)$
- Best fit values for constants A_i and B_i is found to be 2000N and 0.08m respectively.

Scaling – Helbing circular model



- Mass(m) = 80 kg, velocity = v , diameter(d) = 0.6m
- Units for A = $\text{kg m/s}^2 = \text{kg (m/s)}^2/\text{m} = \text{mass} \cdot \text{velocity}^2/\text{diameter} = mv^2/d$
- To get scaled dimensionless value of A , we will divide by mv^2/d to get $A = 15/v^2$
- Similarly, for B , units = $\text{m} = \text{diameter}$
- Hence dividing by d , we get $B = 0.133$

Helbing Elliptical Model



- Takes into account both velocity of approach and distance between particles.

$$\mathbf{f}_{ij} = A e^{-\frac{b_{ij}}{B}} \cdot \frac{\|d_{ij}\| + \|d_{ij} - y_{ij}\|}{2b_{ij}} \cdot \frac{1}{2} \left(\frac{d_{ij}}{\|d_{ij}\|} + \frac{d_{ij} - y_{ij}}{\|d_{ij} - y_{ij}\|} \right)$$

$$y_{ij} = (v_j - v_i) \Delta t$$

$$2b := \sqrt{(\|d_{ij}\| + \|d_{ij} - y_{ij}\|)^2 - (\|y_{ij}\|)^2}$$

- A and B are constants whose best fit values found experimentally are $A = 0.04$ N and $B = 3.22$ m
- The equipotential lines generated by this repulsive force field are elliptical as other pedestrians take into account that more space is required for the next step by the pedestrian.

Scaling – Elliptical Model



- Similar to Circular model scaling as units of A and B are the same.
- Hence, $A = 0.04 * d / mv^2 = 0.0003 / v^2$
- $B = 3.22 / d = 5.367$

Power Law Model



- The power law model suggests that the repulsive force between two pedestrians depends upon their time to collision(τ)
- τ is the time for which two pedestrians could continue walking with their current velocities before they collide

$$\mathbf{F} = - \nabla_{\mathbf{r}} \left(\frac{k}{\tau^2} e^{-\frac{\tau}{\tau_0}} \right)$$

- τ_0 is found to be 3s while $k = 1.5 \text{ kgm}^2$

Scaling – Power Law



- Mass(m) = 80 kg, velocity = v , diameter(d) = 0.6m
- Scaled value of $\tau_o = 3 \cdot v/d = 5 \cdot v$
- Scaled value of $k = 1.5/md^2 = 0.05$

Experiments



Head on Case

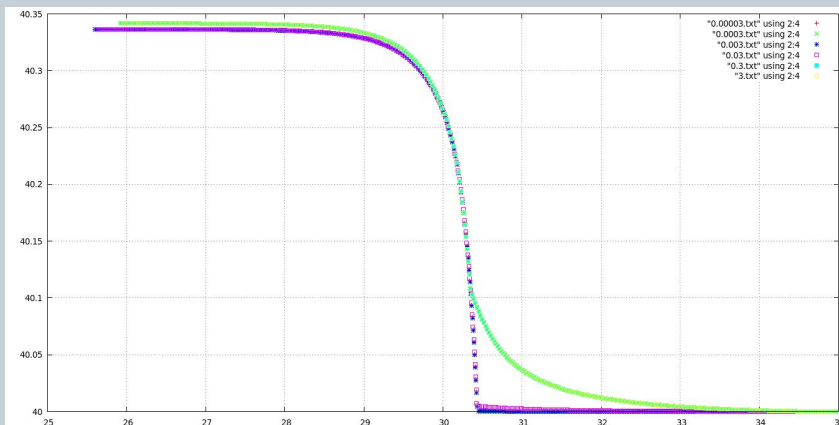


- Experiments have been done primarily for the head-on case where two pedestrians approach towards each other with a slight offset for both goal oriented and direction oriented motion.
- Variations in simulations –
 - Changing parameters of Helbing elliptical and Power Law model
 - Varying the offset and velocity of approach and comparing results across the three different models
- All graphs have been plotted for the pedestrian approaching from (35,40) towards the left. The other pedestrian is not plotted as its trajectory is symmetric
- The goal point for all goal oriented cases is (15,40) and desired velocity for direction oriented cases is (-1,0)

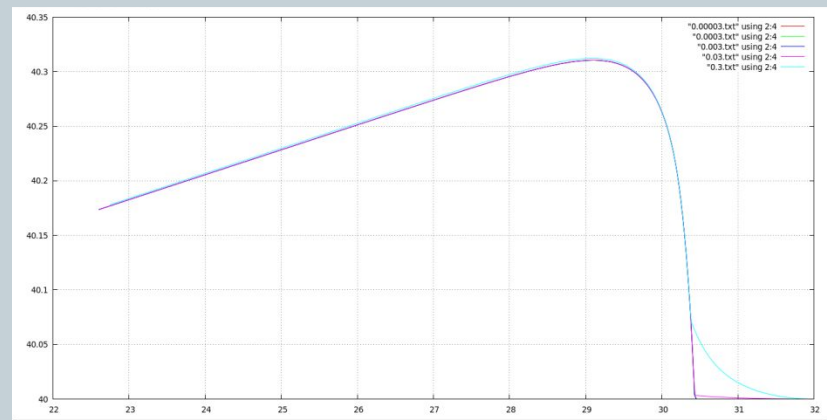
Parameter Dependence – Helbing (A)



- For parameter A, the default value is $0.0003/v^2 = 0.0003$ as $v = 1$ m/s
- This parameter basically increases the magnitude of force and hence the particle starts deviating early as A increases.



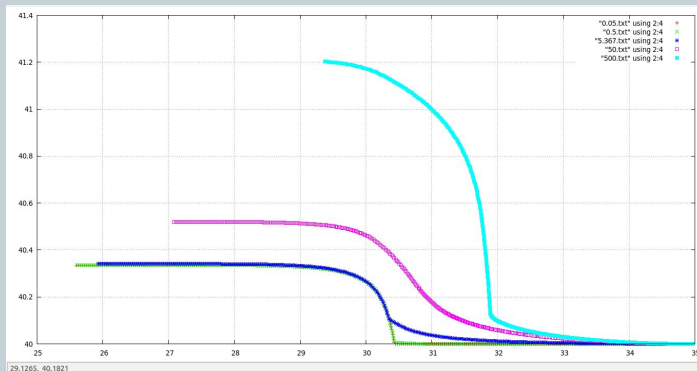
Direction oriented case (y vs x plot)



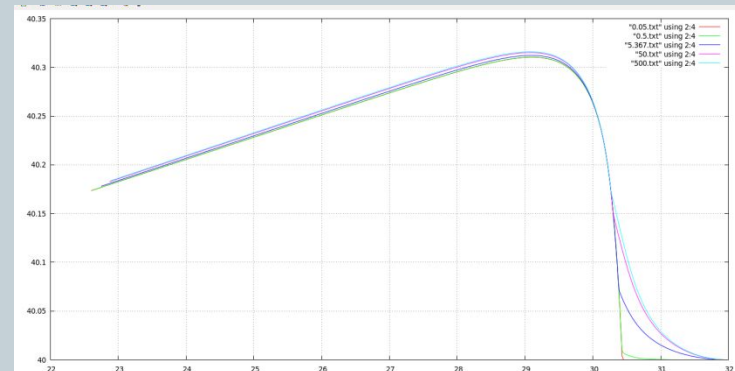
Goal oriented case (y vs x plot)

Parameter Dependence – Helbing (B)

- The sensitivity of the trajectory to this parameter increases as the value of A increases.
- In general, deviation starts occurring earlier if B is higher.
- Results are provided for the case where $A = 0.3$ because for lower values of A there is no significant change in trajectory on varying B .



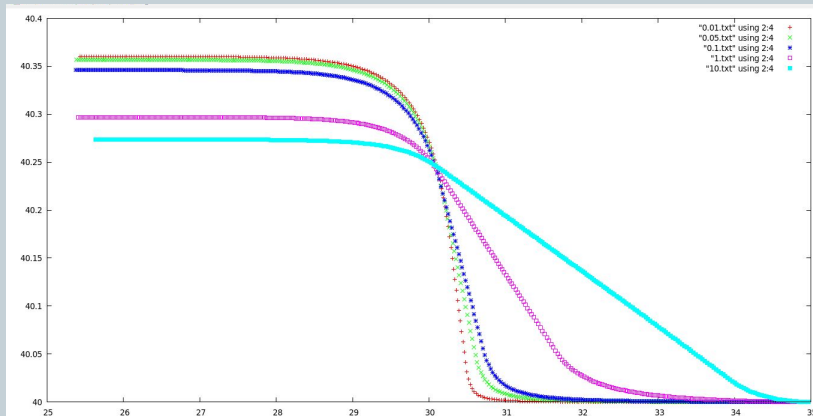
Direction Oriented case (y vs x)



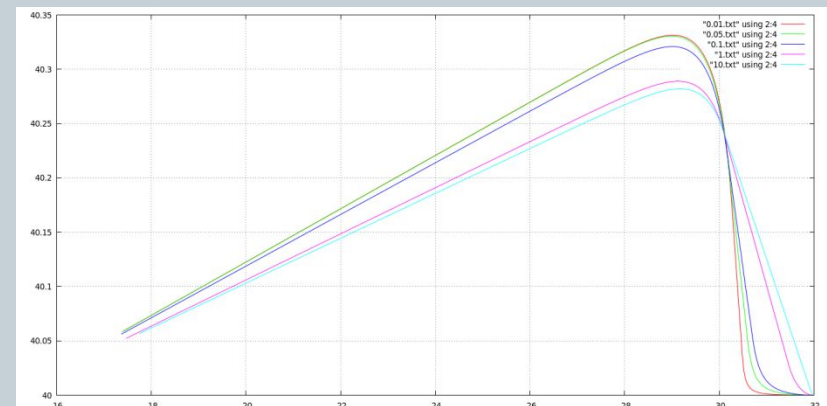
Goal Oriented case (y vs x)

Parameter Dependence – Power Law (k)

- Default value of $k = 0.05$
- k increases the magnitude of force and hence the particle starts deviating earlier as k increases



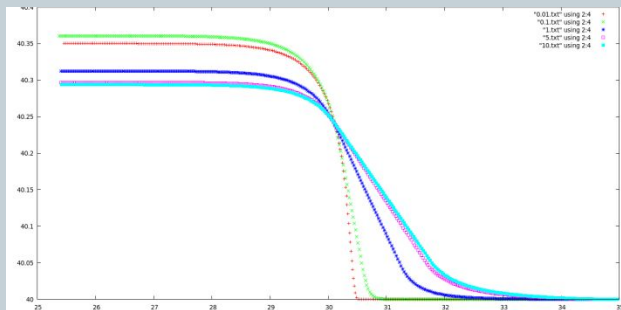
Direction Oriented case (y vs x)



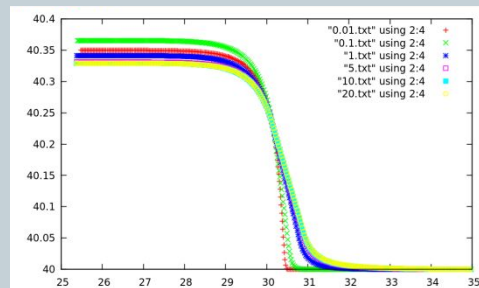
Goal Oriented case (y vs x)

Parameter Dependence – Power Law (τ_o)

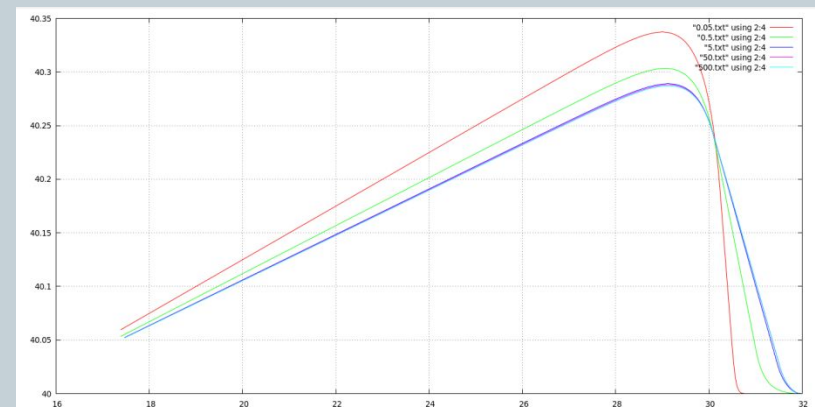
- Default value of $\tau_o = 5v = 5$ as $v = 1$ m/s
- As τ_o increases, deviation starts earlier. Sensitivity of τ_o increases with value of k .



Direction oriented with $k=1$



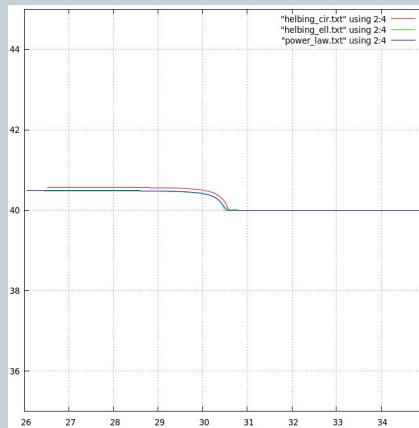
Direction oriented with $k=0.2$



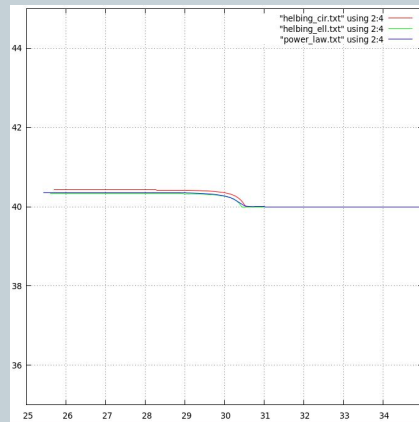
Goal oriented with $k=1$

Model Comparison – Offset change

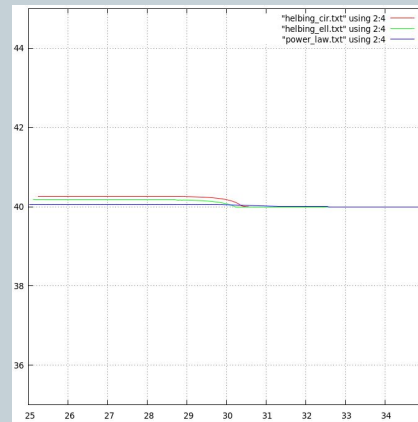
- On increasing offset, deviation in path decreases
- All three models give similar results for small offsets but as we approach 1, where the circular territories of pedestrians just graze each other, deviation by power law and helbing elliptical model immediately goes to zero while helbing circular does not.



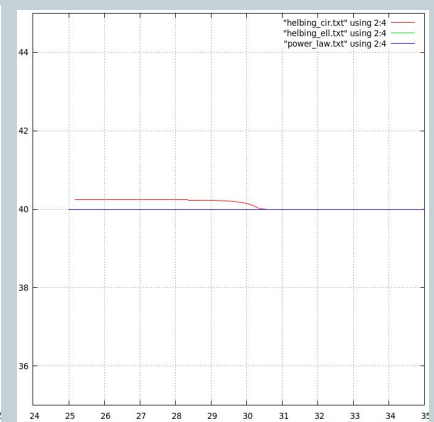
Offset = 0.2



Offset = 0.5



Offset = 0.9

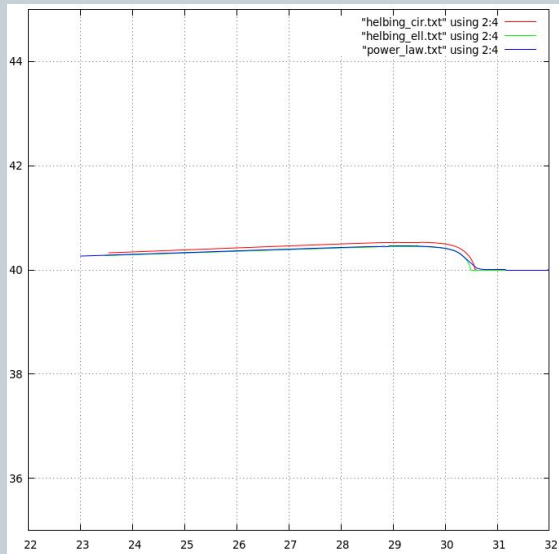


Offset = 1

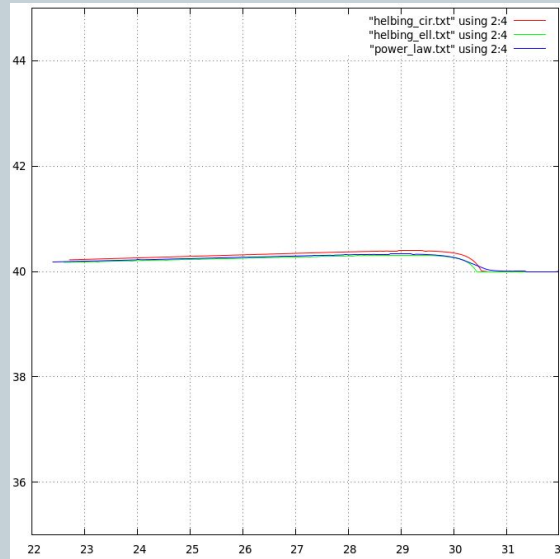
Model Comparison – Offset change



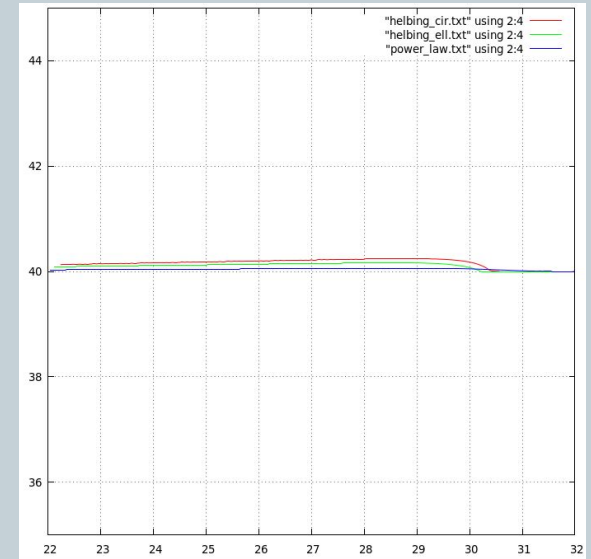
y vs x plots for goal oriented case -



Offset = 0.2



Offset = 0.5

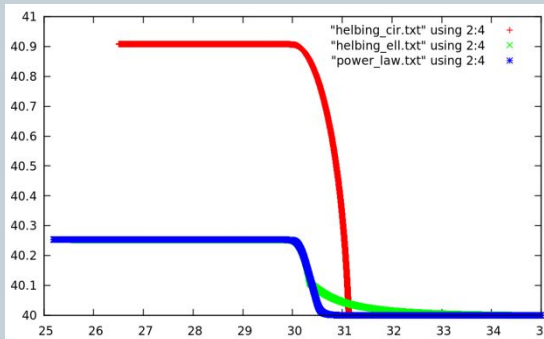


Offset = 0.9

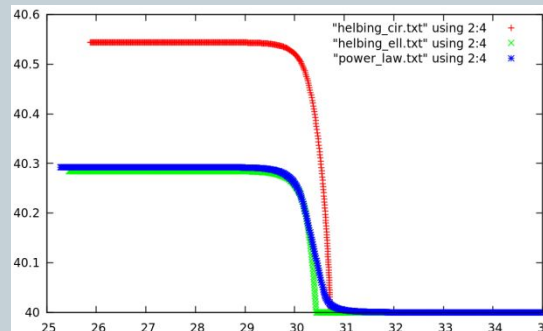
Model Comparison – Velocity change

- Keeping the offset constant, the velocity of approach of both pedestrians was varied and results were compared across models.

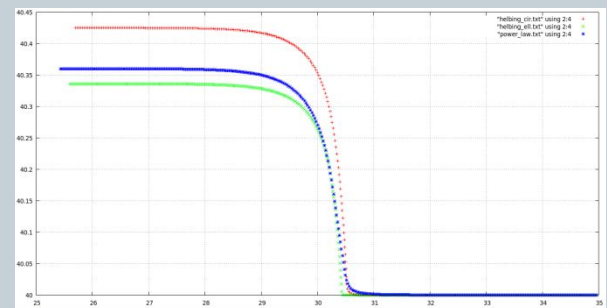
y vs x plots for direction oriented case -



Vel = 0.1



Vel = 0.5

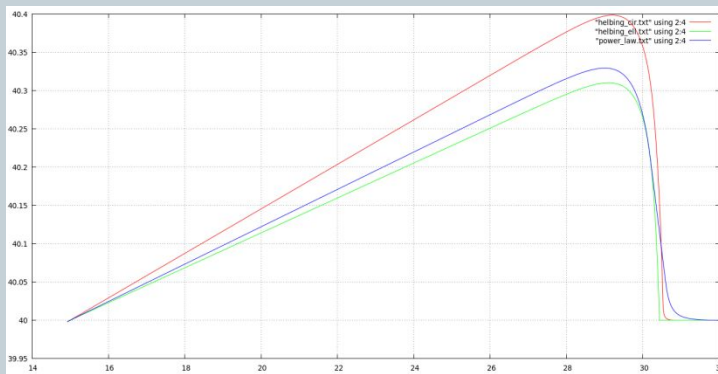


Vel = 1

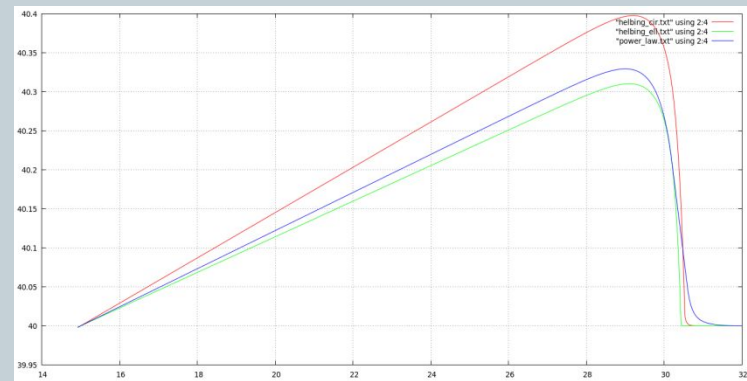
Model Comparison – Velocity change



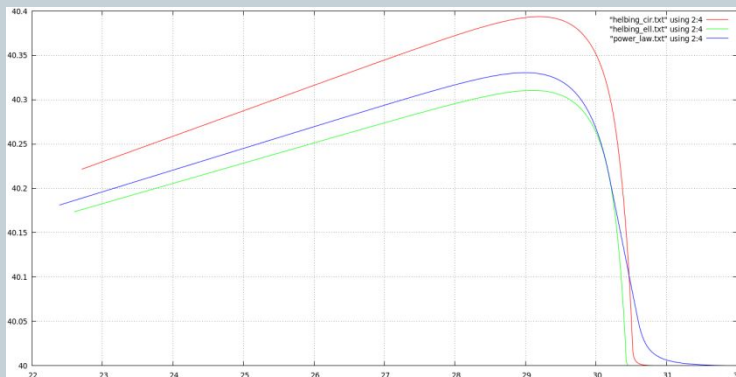
y vs x plots for goal oriented case



Vel = 0.1



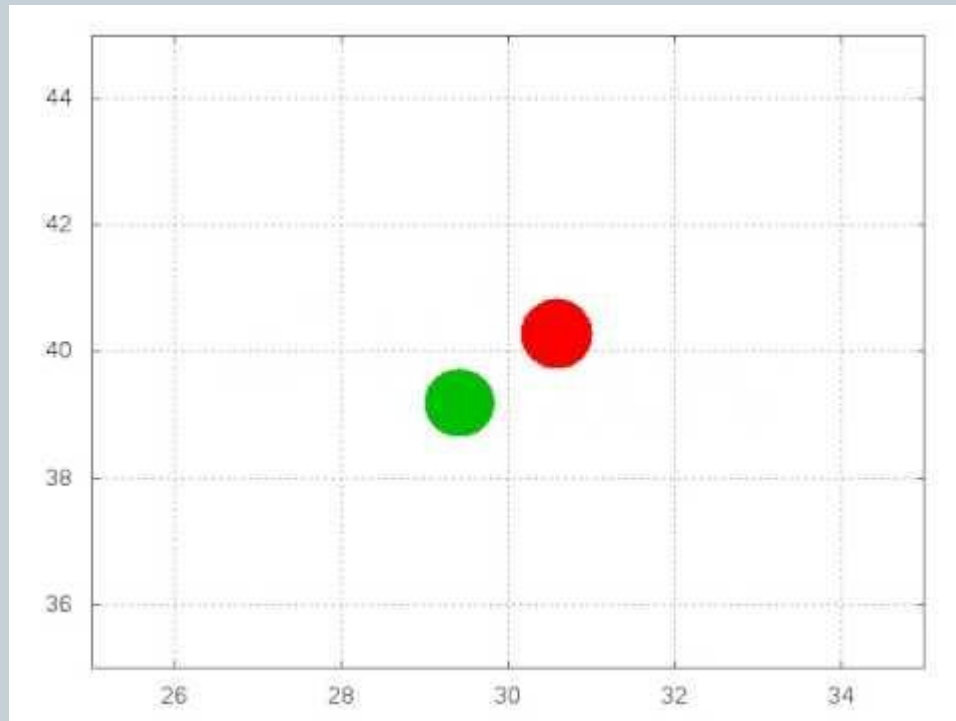
Vel = 0.5



Vel = 1

We can see that since Helbing circular model does not take into account the velocity, trajectories remain unchanged for it with change in velocity

Simulations - Head on case

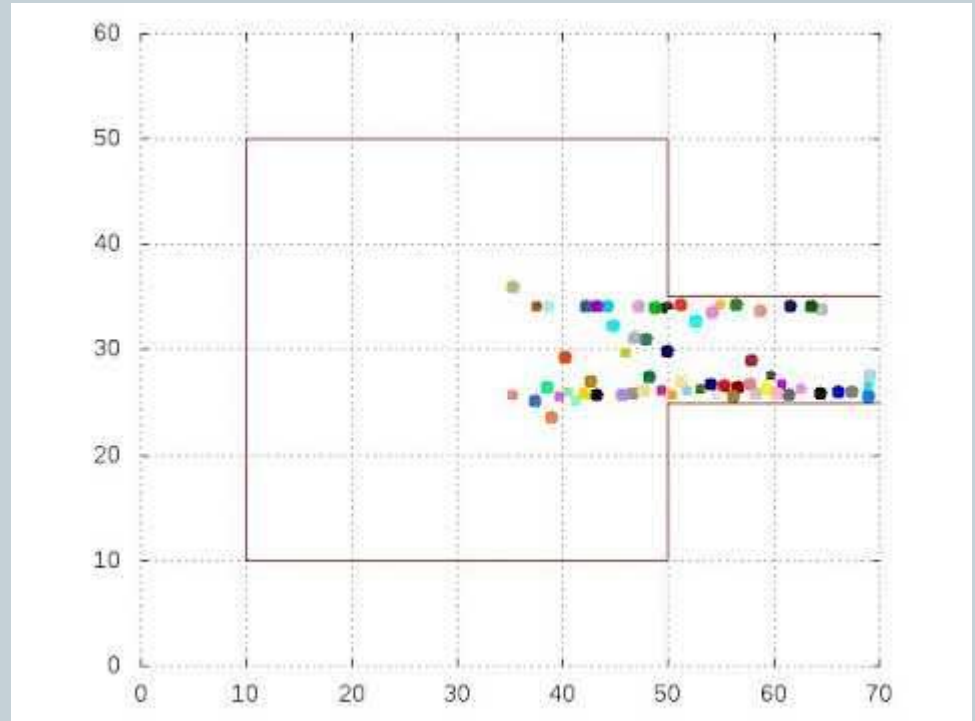


Head on Case

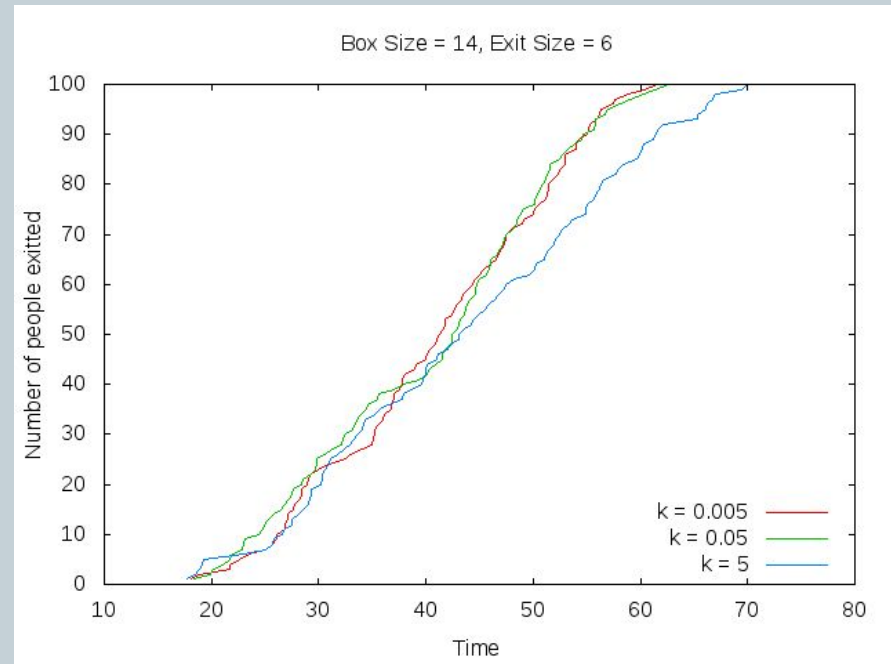
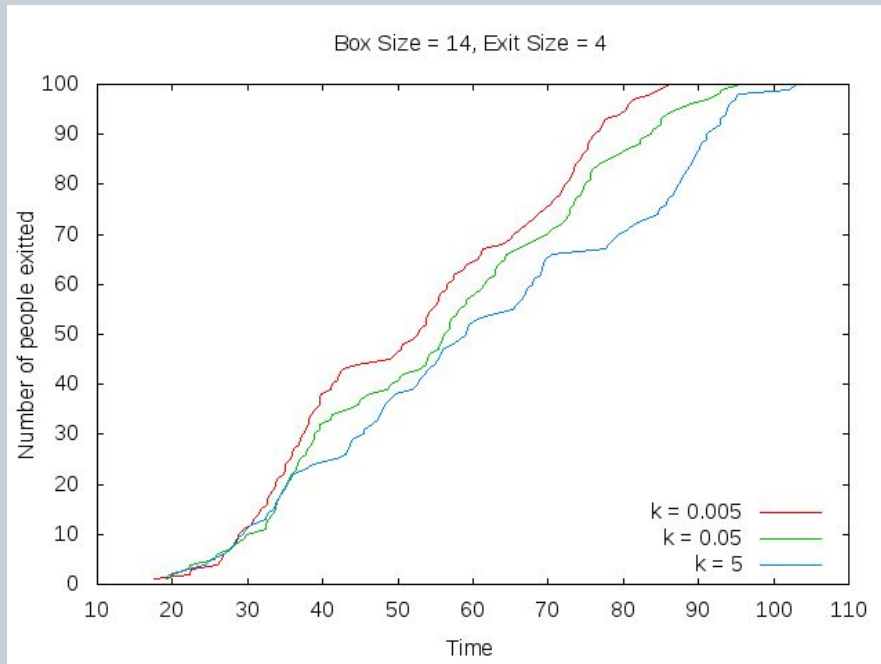
Simulations - Multiparticle system



- Multi-particle system
- Particles are in a confined room with only one exit
- Velocity distribution between particles is a Gaussian distribution
- Model parameters, exit width, box width, velocity distribution, etc are varied



Results - Multiparticle systems



Thank You

