

# CROWD DYNAMICS IN EMERGENCY SITUATIONS

HSO

June 15, 2020

# Outline

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## 1. Problem Statement

- ▶ Simulation with crowds are hard to perform.
- ▶ Frequently humans tend to disregard simulations drills (don't take serious).
- ▶ Is difficult to account for real panic scenario when performing real simulation exercise.
- ▶ Goal is to recover the statuses of the missing or unknown links in the input graph.
- ▶ Difficult to obtain a real sample of the population with different characteristics.

## 2. Contextualization

**Exclusive Gabby Logan interview: 'There was a feeling of guilt that we all came through safe'**

Broadcaster says the Bradford fire that claimed 56 lives in 1985 still haunts her

By Paul Hayward, CLOUTIER WIRE SERVICE  
Using photo: PA Wire



The above image of Hillsborough was taken after the fire at Bradford City's Valley Parade stadium. Photo: PA Wire



**Heysel disaster of 1985 is football's forgotten tragedy and Liverpool and Juventus' minimal reaction prolongs hurt**

Thirty years after 39 fans died at the European Cup final in Brussels the hurt is impossible to erase, partly thanks to the silent and bungling response



Heg: Trapped supporters struggle to escape the Brussels stadium Photo: REX IMAGES

**Police who smeared victims in wake of Hillsborough disaster could face criminal charges, report suggests**

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The Hillsborough disaster, in 1989. Credit: BENSON & CECIL

**It is terrifying to remember Ellis Park disaster – Nomvetho**

By Miriam Jackson - April 11, 2020



Forty-three individuals perished in what stays the most important tragedy in South African sport

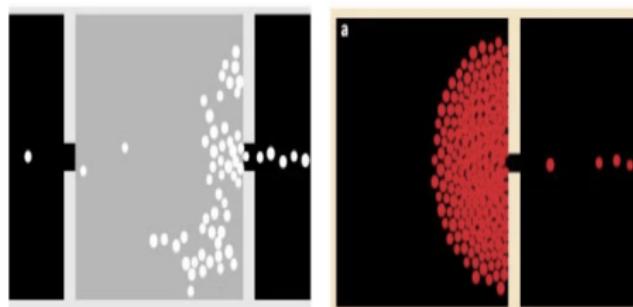
### Observations

- \* Minor small events lead to this chain of disaster
- \* Cigarette on the bench, misbehaviour spectators

### 3. Literature

Dirk Helbing, Ill 'es Farkas, and Tamas Vicsek, "**Simulating dynamical features of escape panic**", Nature, vol. 407, no. 6803, pp. 487–490, 2000

- ▶ Arching - Occurs when large number crowd in high velocity pass through a narrow exit.
- ▶ Exits have limited workload
- ▶ Over time an arch of crowded is formed
- ▶ Rerouting become vital



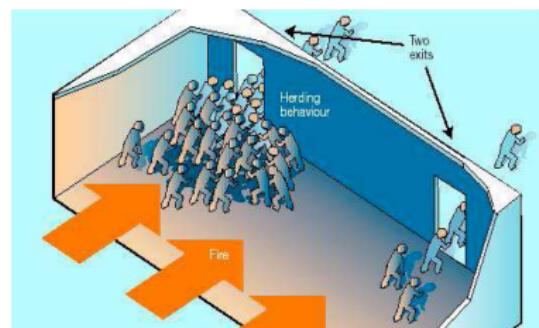
### Observations

- \* In the majority of the case the exit take much more time to occur.
- \* The number of stampeded victims occurs in this situation
- \* Fragile victims account for the majority of the victims

### 3. Literature

Noor Akma Abu Bakar, Khalid Adam, Mazlina Abdul Majid, and Mario Allegra, **A simulation model for crowd evacuation of fire emergency scenario**, in 2017 8th International Conference on Information Technology (ICIT). IEEE, 2017, pp.361–368

- ▶ With panic agents loose rationality.
- ▶ Lack of coordination
- ▶ Lack of group vision
- ▶ Herding - tends to follow other behaviour



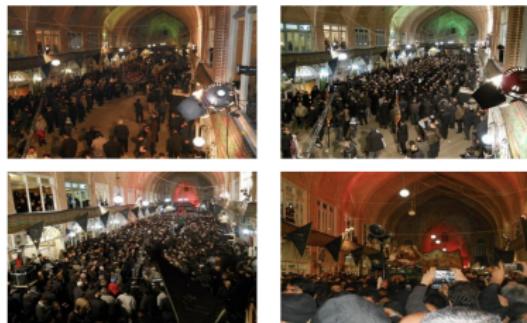
### Observations

- \* Other exist may offer better advantages (larger capabilities).
- \* Herding behaviour leads to the following of others are doing
- \* Persons assumes others can lead them to safety.

### 3. Literature

Saeed Alighadr, Abdolhossein Fallahi, Junji Kiyono, Nabilashuada Rizqi Fi-trasha, and Masakatsu Miyajima, **Emergency evacuation during a disaster, studycase: “timche muzaffariyye–tabriz bazaar”** iran, Lisbon: Conference proceeding of, 2012

- ▶ Simulates movement and decision making by means of adding the psychological forces to the physical forces.
- ▶ Considers avoidance, overtaking, and pass between elements naturally



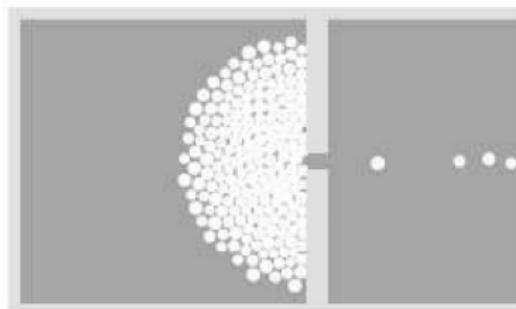
### Observations

- \* Persons can avoid others in short distance.
- \* Different genre of natural obstacles are modeled

### 3. Literature

João E. Almeida, Rosaldo Rosseti, Antonio Leça Coelho, **Crowd Simulation Modeling Applied to Emergency and Evacuation Simulations using Multi-Agent Systems**, arXiv preprint arXiv:1303.4692 (2013).

- ▶ Present the main phenomena in crowd evacuations
- ▶ Presents a simulation scenario
- ▶ Presents a frameworks for crowd simulation in emergency
- ▶ Allows easy inclusion algorithms
- ▶ Modular design based OO



### Observations

- \* Allows inclusion social forces
- \* Allows inclusion some BDI agents aspects such as sensors real word, social forces and interaction other agents.

## 4. Research Hypothesis

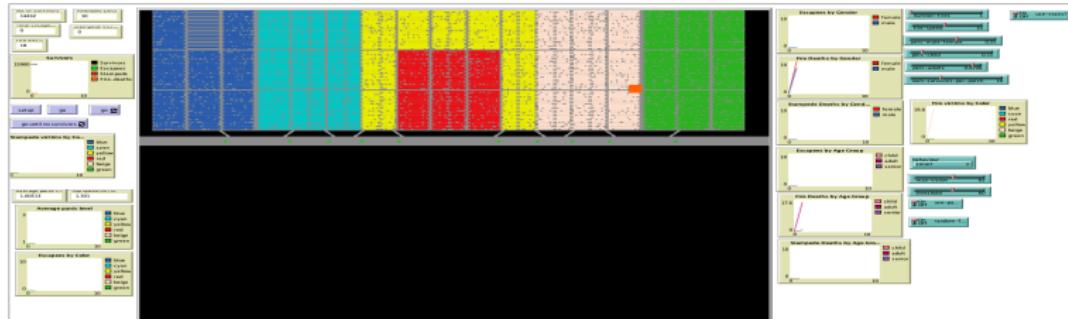
### Questions?

- ▶ Is possible to demonstrate how some strategies influence the number of victims in an emergency?
- ▶ How The panic influences the number of victims?
- ▶ How the infrastructure number of exits and fire speed influences number victims
- ▶ Which are the most susceptible victims ?
- ▶ Which are the dangerous areas and safe zones?

### Suggestions

- ▶ Construct a ABM to capture the fundamental characteristics inherent to human behaviour.
- ▶ The framework should enable detail analysis and user simulation control.
- ▶ Collect statistics regarding agent characteristics.

## 5. Proposed Model/Scenario



### Details

- ▶ Spectators seat on benches (colors)
- ▶ Fire can occur on any place
- ▶ Agent can only travel through corridors and stairs
- ▶ Agents try to escape fire going to exits
- ▶ Fire spreads omni-directional (Square)
- ▶ Several parameters can be changed in run-time
- ▶ Detailed statistics for each agent class.

## 5. Agent Parameters

Parameter	Description		
Age group	Normal distribution - Pordata: 3 Categories *Child *Adult *Elderly	Panic Level (1 to 3)	*Level 1 - All agents base *Level 2 - Fire in agent's vision. Agent's speed increases fast pace (1.8056 m/s). *Level 3 - Fire nearer (half the distance that the agent can see). Agent's speed increases to a running speed (2.5 m/s).
Gender	Normal distribution - Pordata: *Male: 48% *Female: 52%	Mass	Agent mass (kg) drawn from a normal distribution depending on their age category and gender. STD = 4 all cases.  Child Female: mean=35 kg Male: mean=40 kg  Adult/Elderly: mean=57.7 Female: mean=57.7 Male: mean=57.7
Speed	Each agent has a base walking speed depending on their age category: *Child: 0.3889m/s *Adult: Uniform distribution between 1.4778m/s and 1.5083m/s *Elderly: Uniform distribution between 1.2528m/s and 1.3194m/s	Threshold	Threshold value Value between 10 and 100. Scaling factor for pressure.
Max Vision	Uniform distribution between 0 (vision can be extremely poor due to natural blindness or onset of smoke) and a maximum that can be set between 20 and 100.	Fire speed	speeds from 4m/s up to 20m/s.

### Model

$$F_p = \sum_a i \in A_p^N mass_a \times speed_a$$

$$health_a = mass_a \times speed_a \times th$$

$$F_p > health_a \rightarrow agent_a Dies$$

## 5. Evacuation Strategies

- ▶ **Full Knowledge Strategy** - All agents have full knowledge and select the closest available exit based on best first.
- ▶ **Follow The Crowd Strategy** - Agent follow path that other agents in the surroundings follow, if they see exit on view, the run straight to it.
- ▶ **Follow the Leader Strategy** - Some agents have full knowledge, other simple follow if they are in sight. Otherwise they use follow crowd strategy.

## 5. Behaviours

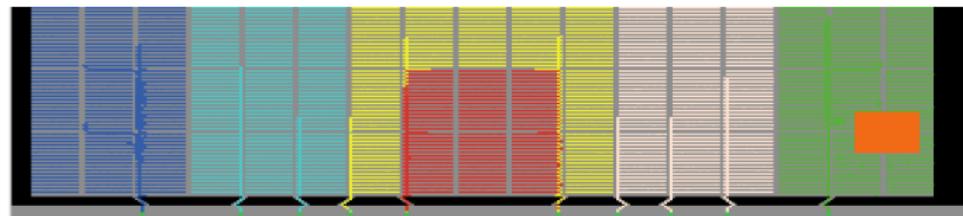
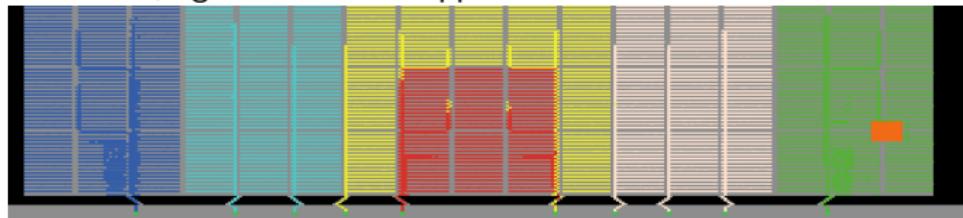
If panic behaviour, agent speed is changed according to the following rules

Level 1 - All agents base according to the distribution in table

Level 2 - Fire in agent's vision. Agent's speed increases fast pace (1.8056 m/s).

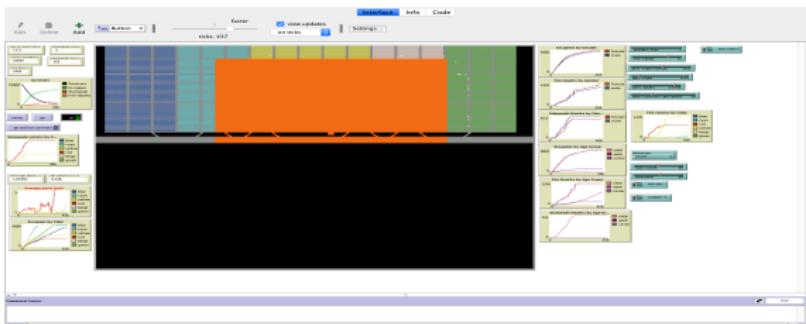
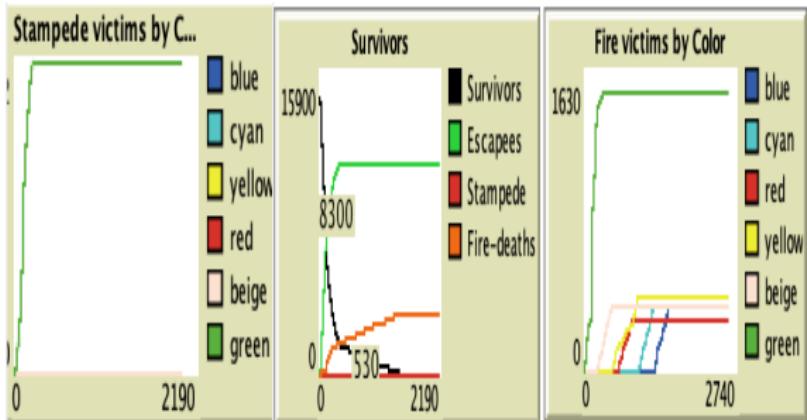
Level 3 - Fire nearer (half the distance that the agent can see). Agent's speed increases to a running speed (2.5 m/s).

If fire is near, agent run in the opposite direction of the fire



## 5. Scene Constraints

- ▶ Number of exits
- ▶ Fire speed
- ▶ Exit location
- ▶ Fire location



# 6. Results - Evacuation Strategies

Table 2: Performance evaluation of Full strategy.

Victims	Strat	Vision	Th	#	Major Seat
By Stamp	Full	50	50	0	-
By Fire	Full	50	50	2673	Yellow
By Stamp	Full	75	50	0	-
By Fire	Full	75	50	2550	Yellow
By Stamp	Full	100	50	0	-
By Fire	Full	100	50	2194	Blue
By Stamp	Full	50	75	10	Red
By Fire	Full	50	75	2025	Yellow
By Stamp	Full	75	75	0	-
By Fire	Full	75	75	2015	Yellow
By Stamp	Full	100	75	0	Blue
By Fire	Full	100	75	1945	Blue
By Stamp	Full	50	100	30	Red
By Fire	Full	50	100	2214	Yellow
By Stamp	Full	75	100	12	Blue
By Fire	Full	75	100	2219	Yellow
By Stamp	Full	100	100	29	Blue
By Fire	Full	100	100	2220	Blue

Table 3: Performance evaluation of Follow Strategy.

Victims	Strat	Vision	Th	#	Major Seat
By Stamp	Follow	50	50	150	Yellow
By Fire	Follow	50	50	3654	Yellow
By Stamp	Follow	75	50	177	Red
By Fire	Follow	75	50	3550	Yellow
By Stamp	Follow	100	50	173	Red
By Fire	Follow	100	50	3439	Blue
By Stamp	Follow	50	75	110	Red
By Fire	Follow	50	75	3025	Yellow
By Stamp	Follow	75	75	115	Red
By Fire	Follow	75	75	3567	Yellow
By Stamp	Follow	100	75	200	Blue
By Fire	Follow	100	75	3945	Blue
By Stamp	Follow	50	100	300	Red
By Fire	Follow	50	100	3214	Yellow
By Stamp	Follow	75	100	123	Blue
By Fire	Follow	75	100	3219	Yellow
By Stamp	Follow	100	100	129	Blue
By Fire	Follow	100	100	4220	Blue

Table 4: Performance evaluation of Follow Leader Strategy.

Victims	Strat	Vision	Th	#	Major Seat
By Stamp	Leader	50	50	23	Yellow
By Fire	Leader	50	50	2783	Yellow
By Stamp	Leader	75	50	19	Red
By Fire	Leader	75	50	2698	Yellow
By Stamp	Leader	100	50	7	Red
By Fire	Leader	100	50	2114	Blue
By Stamp	Leader	50	75	29	Yellow
By Fire	Leader	50	75	2654	Yellow
By Stamp	Leader	75	75	37	Red
By Fire	Leader	75	75	2567	Yellow
By Stamp	Leader	100	75	33	Yellow
By Fire	Leader	100	75	2764	Blue
By Stamp	Leader	50	100	74	Yellow
By Fire	Leader	50	100	2265	Yellow
By Stamp	Leader	75	100	64	Yellow
By Fire	Leader	75	100	2130	Yellow
By Stamp	Leader	100	100	53	Red
By Fire	Leader	100	100	2003	Red

## Observations

We can observe that setting a strategy to follow the crowd leads to a increase of the numbers of stampede victim in vast number.

## 6. Results - Behaviour/Constraints

**Table 7:** Performance evaluation of fire speed (Fixed strategy,  
 $Vision = 60, Th = 60$ ).

Victims	speed m/s	#	Major Seat
By Stamp	6	62	Red
By Fire	6	1456	Red
By Stamp	8	77	red
By Fire	8	1543	Blue
By Stamp	10	113	Red
By Fire	10	1536	Red
By Stamp	12	162	Red
By Fire	12	1652	Red
By Stamp	14	252	Red
By Fire	14	1612	Red
By Stamp	16	300	Red
By Fire	16	1734	Red
By Stamp	18	357	Red
By Fire	18	3543	Red
By Stamp	75	471	Red
By Fire	75	4326	Cyan

**Table 8:** Performance evaluation of fire location (Fixed strategy,  $Vision = 60, Th = 60$ ).

Victims	Location	#	Major Seat
By Stamp	SE/NE	72	Cyan
By Fire	SE/NE	2544	Cyan
By Stamp	W	107	Blue
By Fire	W	2323	Blue
By Stamp	Middle	103	Red
By Fire	Middle	2753	Yellow
By Stamp	NE	80	Green
By Fire	NE	2450	Red
By Stamp	S	50	Red
By Fire	S	1612	Red

**Table 6:** Performance evaluation of fire exit (Fixed strategy,  $Vision = 60, Th = 60$ , fire speed = 8m/s, panic = true).

Victims	# exits	#	Major Seat
By Stamp	6	835	Red
By Fire	6	2367	Red
By Stamp	8	562	Red
By Fire	8	1543	Blue
By Stamp	10	89	Red
By Fire	10	1203	Red

## Observations

In this scenario we considered the variation of the number of exits. Is possible to observe the the number of fire victims and stamped increase when the number of exist are reduced, due to the crowd concentration near those exists.

## 7. Demo

## 8. Conclusions

- ▶ Full or partial information is vital, leads to an increase of stampede victims due to arching nearing the exits.
- ▶ Following the crowd, leads to a large number of stampede victims.
- ▶ Follow the leader reduced greatly the number of victims.
- ▶ Fragile agents account for the + stamped victims
- ▶ Number of exist constraints the crowd evacuation and leads to stamped
- ▶ Fire near the exits or lower benches leads to fire victims (Trapped)

## Observations

- \* Population sample may not totally represent the people that goes to live spectacles
- \* Distributions can be easily changed and parametrized
- \* New strategies and behaviours can be easily modelled
- \* Fire speed on closed and open fields can be modelled

## 9. References