Aalto University
School of Science

Patient and impatient pedestrians in a spatial game of egress congestion

Harri Ehtamo, Aalto University, Espoo, Finland
Co-authors: Anton von Schantz, Simo Heliövaara
harri.ehtamo@aalto.fi

OR2015, Vienna, Austria, Sep. 1-4, 2015
INFORMS 2014, San Francisco, Nov. 9-12, 2014

Systems Analysis Laboratory

Evacuation simulations

- Crowds evacuating through narrow bottlenecks may create clogging and jams that slow down the egress flow.
- Pushing towards the exit may create faster-is-slower effect.
- We propose a spatial game to model the interaction of agents in such situations.
- We apply the game model to a continuous time egress simulation FDS+Evac (http://www.vtt.fi/proj/fdsevac/?lang=en).

Previous research

- Evacuation experiments and computer simulations: S. P. Hoogendorn et al., 2005; Heliövaara et al., 2012; D. Helbing et al., 2000; A. Kirchner et al. 2003.
- Social psychology of panic: A. Mintz, 1951.
- Prisoner's Dilemma (PD) game: R. Brown, 1965; J. S. Coleman, 1990.
- Spatial games and computation: M. A. Nowak and R. M. May, 1992; M. Sysi-Aho et al., 2005.
- Biological evolution and games: J. Maynard Smith, 1982.

Game matrix for agent-agent interaction

Estimated evacuation time of agent i:

$T_i = \frac{\lambda_i}{\beta}$. Denote $T_{ij} = (T_i + T_j)/2$.

Available safe egress time (ASET): T_{ASET}

Cost function: $u(T_i;\ T_{ASET})$

Players' strategies: Patient, Impatient

The rules of the game:

(i) An impatient agent i can overtake its patient neighbor j ⇒ the cost of agent i decreases by $\Delta u(T_{ij}) \simeq u'(T_{ij})\Delta T$.

(ii) Two patient agents do not interact with each other ⇒ their costs do not change.

(iii) Two impatient agents, neither can overtake the other. Instead they will face a conflict with equal chance of getting injured ⇒ Cost of conflict C.

Game matrix:

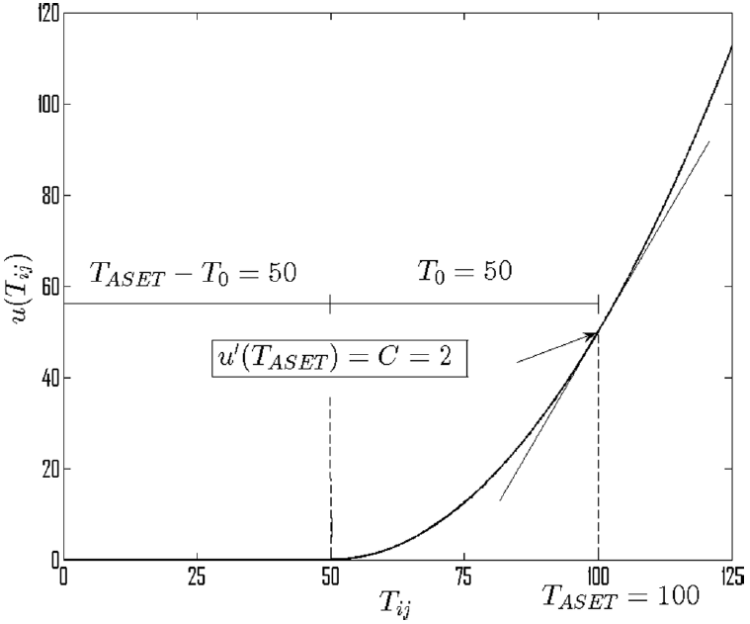
	Impatient	Patient
Impatient	$\frac{C}{\Delta u(T_{ij})}, \frac{C}{\Delta u(T_{ij})}$	$-1, 1$
Patient	$1, -1$	$0, 0$

The game to be played:

(i) prisoner's dilemma (PD) if $0 < \frac{C}{\Delta u(T_{ij})} \leq 1$,

(ii) hawk-dove (HD) if $\frac{C}{\Delta u(T_{ij})} > 1$.

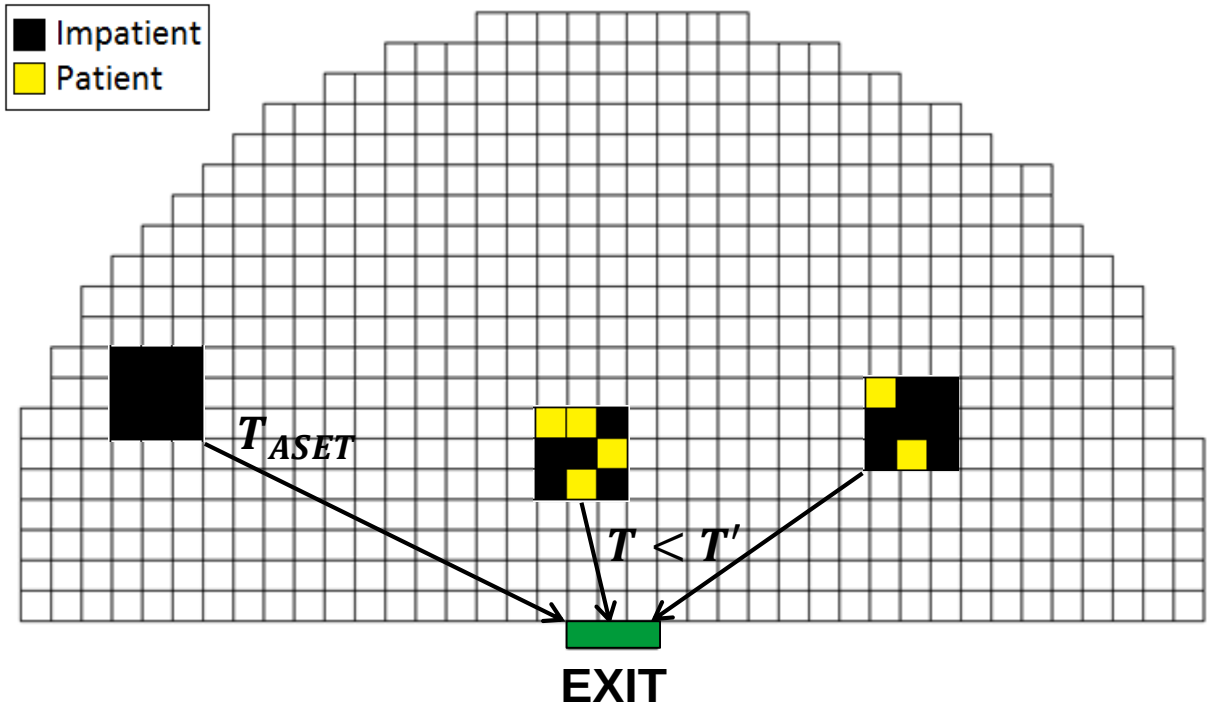
Cost function:



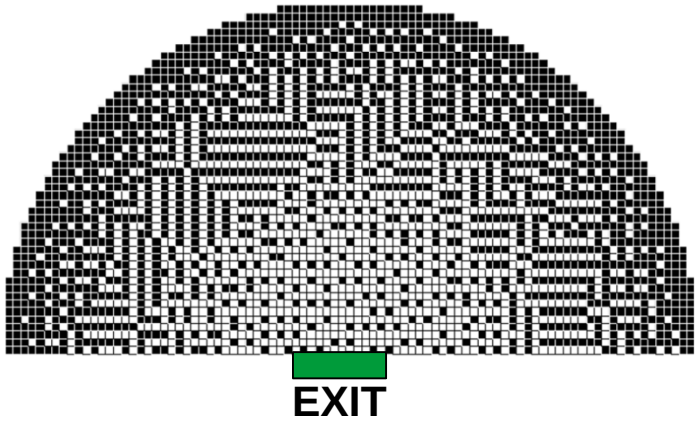
E.g.: $u(T_{ij}) = \begin{cases} 0, & if\ T_{ij} < T_{ASET} - T_0, \\ \frac{C}{2T_0}(T_{ij} - T_{ASET} + T_0)^2, & if\ T_{ij} > T_{ASET} - T_0. \end{cases}$

$\Rightarrow \frac{C}{\Delta u(T_{ij})} \simeq \frac{T_0}{T_{ij} - T_{ASET} + T_0}.$

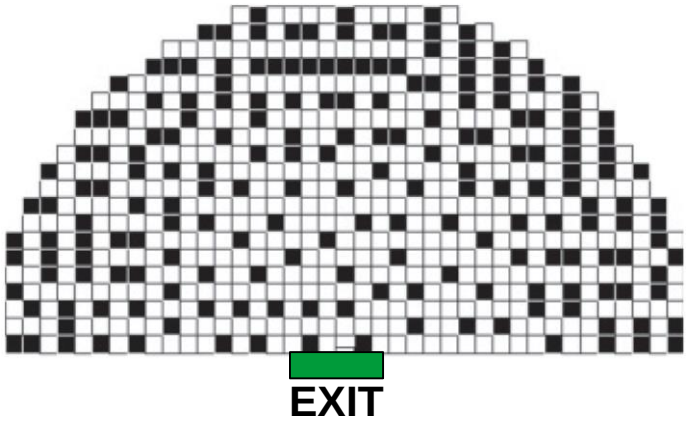
Spatial setting, BR-dynamics, and shuffle update rule



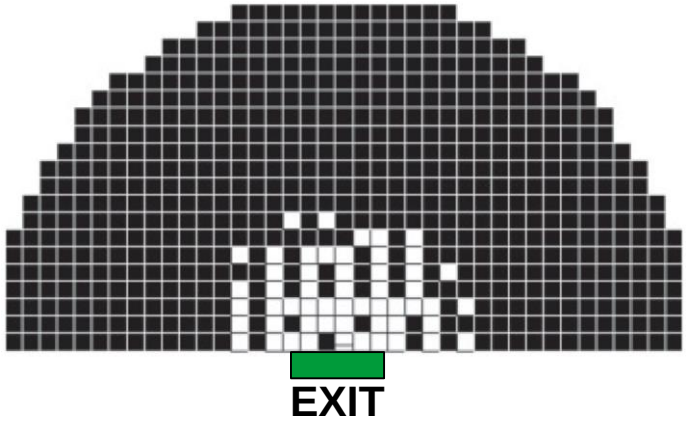
Equilibria in discrete grid



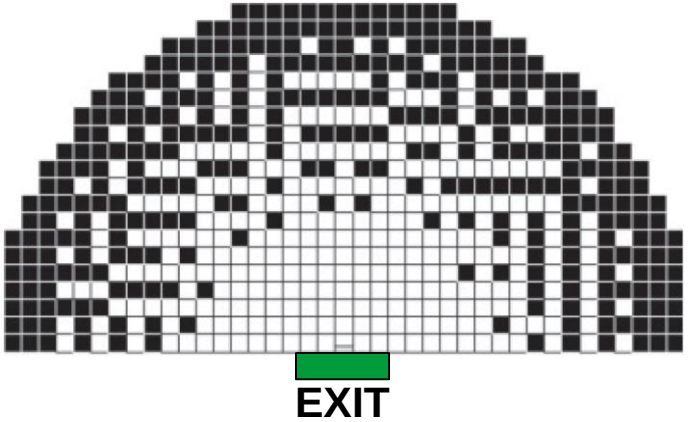
$T_{ASET} = T_0 = 2800\ s,\ 3180$ agents



$T_{ASET} = 1500s, T_0 = 1500s, 628$ agents

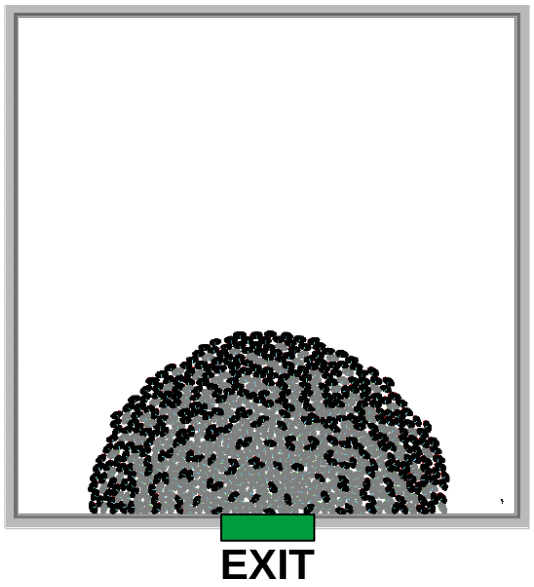


$T_{ASET} = 100s, T_0 = 100s, 628$ agents

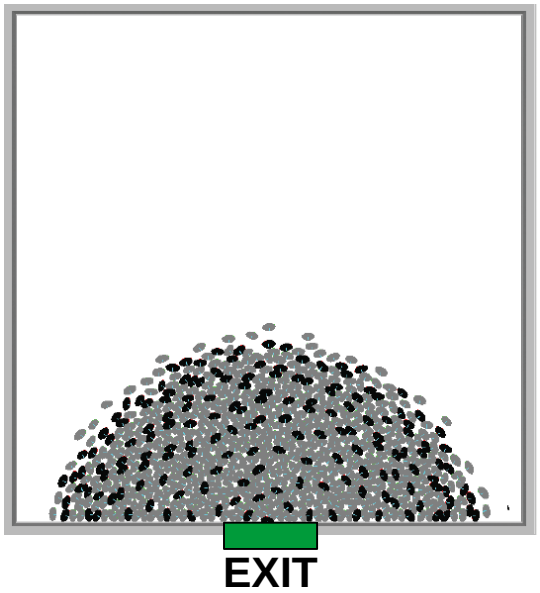


$T_{ASET} = 500s, T_0 = 400s, 628$ agents

Equilibria in continuous space: FDS+Evac simulations



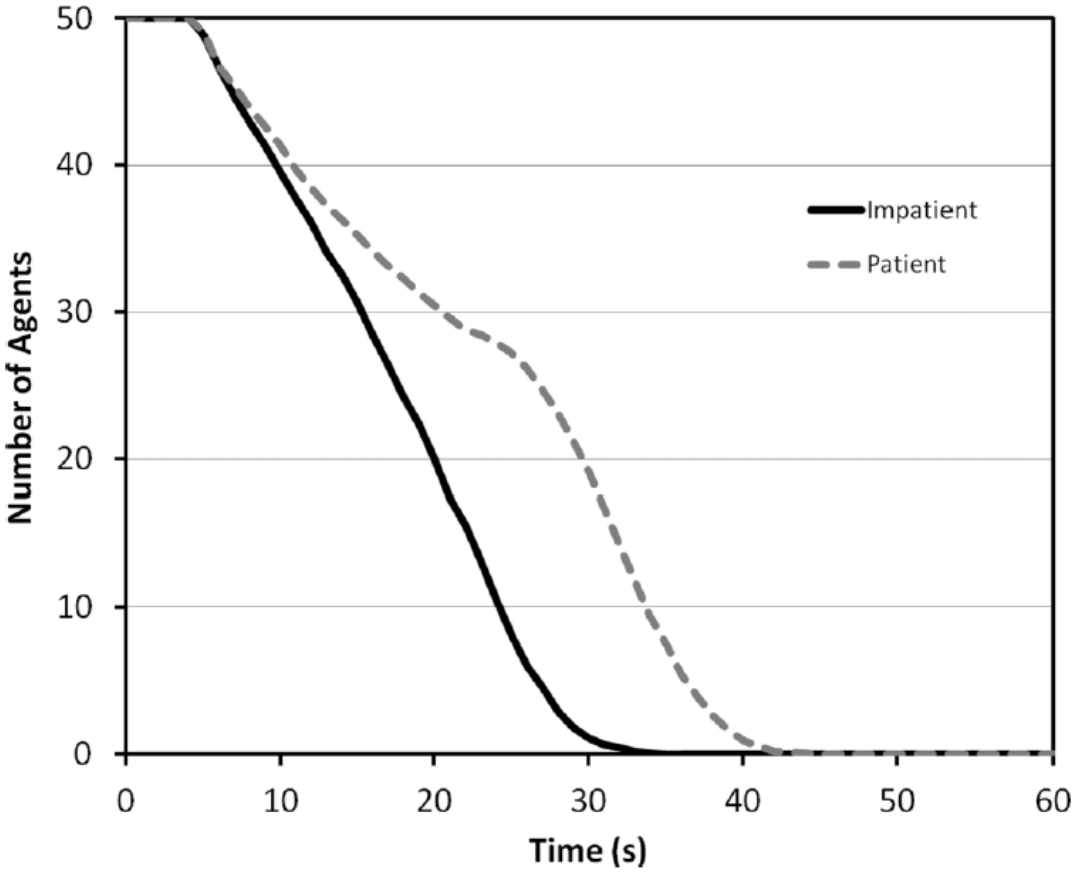
$T_{ASET} = 500s, T_0 = 500s, 628$ agents



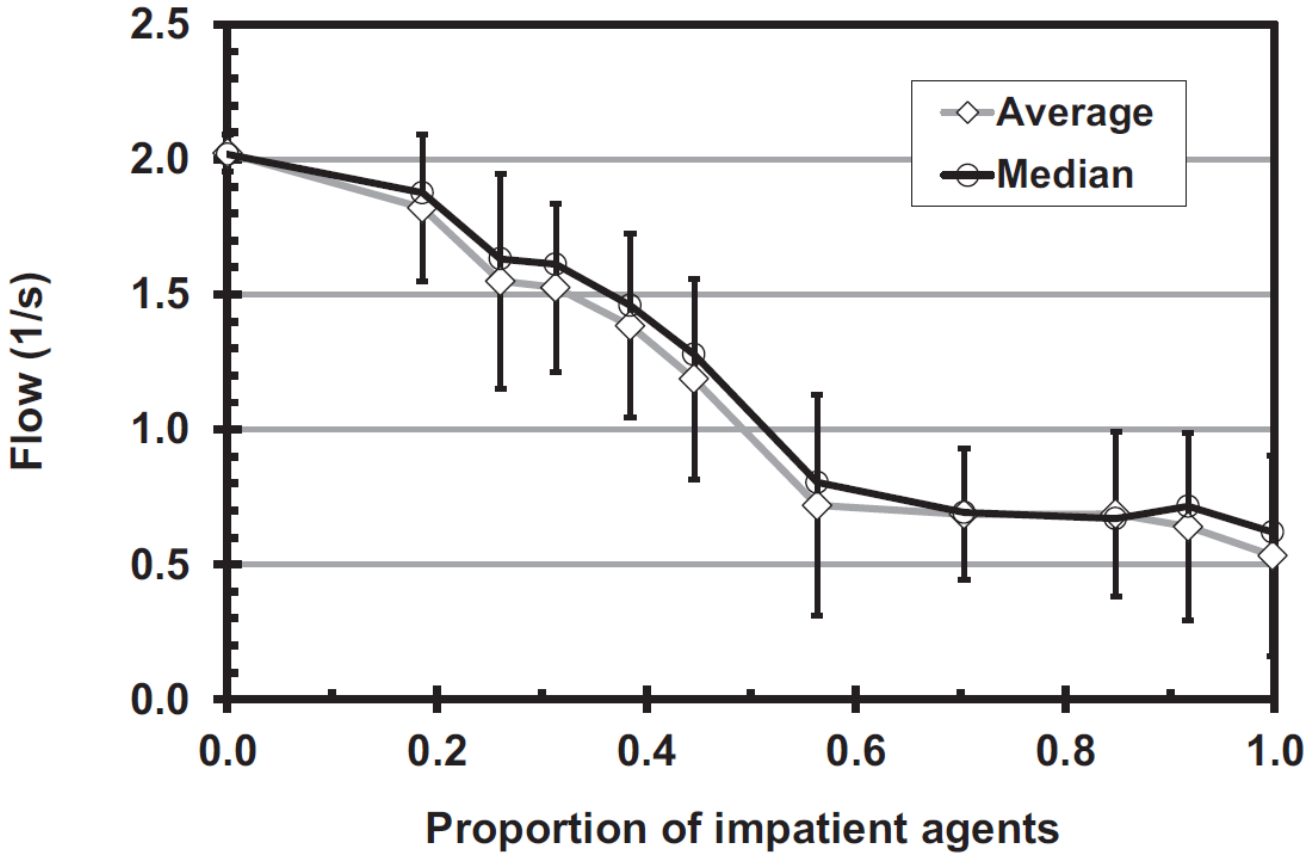
$T_{ASET} = 1500s, T_0 = 1500s, 628$ agents

- Impatient agents: do not avoid contacts with other agents; accelerate faster to their target velocity; move more nervously.

Simulations with fixed strategies



Faster-is-slower effect



Conclusions

- Spatial game model describes when, why and how the crowd members adopt impatient pushing behavior.
- FDS+Evac simulation software is based on physics ⇒ simulations too heavy.
- We study the embedding of our spatial game model to the CA-model developed by A. Kirchner et al., 2003 ⇒ simulation of agent flow is easy, A. von Schantz and H. Ehtamo, 2014.
- Then the incident commander could give timely and accurate instructions with a real-time model.

References

- S. P. Hoogendorn and W. Daamen, Transp. Sci. 39, 147 (2005).
- D. Helbing, I. Farkas, and T. Vicsek, Nature (London) 407, 487 (2000)
- A. Kirchner, K. Nishinari, and A. Schadschneider, Phys. Rev. E 67, 056122 (2003).
- A. Mintz, J. Abnorm. Soc. Psychol. 46, 150 (1951).
- R. Brown, *Social Psychology* (Free Press, New York, 1965)
- J. S. Coleman, *Foundations of Social Theory* (Belknap Press of Harvard University, Cambridge, MA, 1990).
- M. A. Nowak and R. M. May, Nature (London) 359, 826 (1992).
- M. Sysi-Aho, J. Saramäki, J. Kertész, and K. Kaski, Eur. Phys. J. B 44, 129 (2005).
- J. Maynard Smith, *Evolution and the Theory of Games* (Cambridge University Press, Cambridge, 1982).

Our research

- A. von Schantz and H. Ehtamo, Lecture Notes in Computer Science, Vol 8610, 37, (Springer, 2014).
- S. Heliövaara, H. Ehtamo, D. Helbing, and T. Korhonen, Phys. Rev. E 87, 012802 (2013).
- S. Heliövaara, J.-M. Kuusinen, T. Rinne, T. Korhonen, and H. Ehtamo, Saf. Sci. 50, 221 (2012).
- S. Heliövaara, T. Korhonen, S. Hostikka, and H. Ehtamo, Build. Environ. 48, 89 (2012).
- H. Ehtamo, S. Heliövaara, T. Korhonen, and S. Hostikka, Adv. Complex Syst. 13, 113 (2010).
- T. Korhonen and S. Hostikka, *Fire Dynamics Simulator with Evacuation: FDS+Evac — Technical Reference and User's Guide*, VTT Working Papers 119 (VTT Technical Research Centre of Finland, Espoo, Finland, 2009).
- T. Korhonen, S. Hostikka, S. Heliövaara, H. Ehtamo, and K. Matikainen, in *Proceedings of the 7th Asia-Oceania Symposium on Fire Science & Technology, 20-22 September 2007* (Hong Kong Polytechnic University, Hong Kong, 2008).