Evacuation modelling and Virtual Reality for fire safety engineering

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Politecnico di Bari

2004-2006. Bsc Civil Engineering

2006-2008. Msc Transportation Engineering

2009-2012. European Phd. Thesis: “Evacuation modelling in road tunnel fires, Visiting Phd student at GIDAI Group, Universidad de Cantabria (Spain)

2012. Researcher. Fire Research Division, NIST (USA). Department of Commerce of the US government.

2013. Researcher. Department of Psychology I, University of Würzburg (Germany).

2014-... <u>Associate Senior Lecturer</u>, Department of Fire Safety Engineering, Lund University (Sweden)

Outline

- Evacuation research at LU
- Overview of evacuation modelling for underground facilities
- Virtual Reality for evacuation research

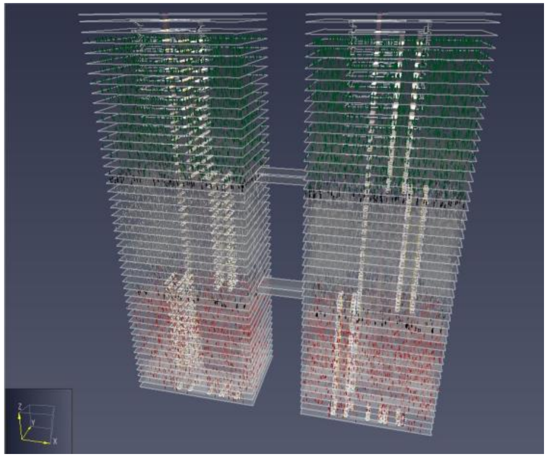
Evacuation Research at LU

EVACUATION RESEARCH METHODS

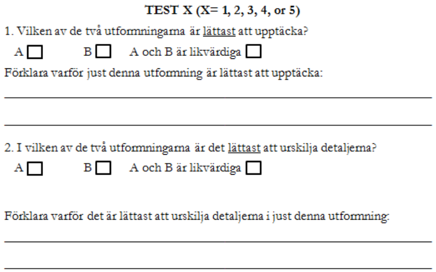
Field experiments

Laboratory experiments (e.g. VR)

Evacuation modelling



Questionnaires



TEST X (X= 1, 2, 3, 4, or 5)

1. Vilken av de två utformningarna är lättast att upptäcka?

A ☐ B ☐ A och B är likvärdiga ☐

Förklara varför just denna utformning är lättast att upptäcka:

2. I vilken av de två utformningarna är det lättast att urskilja detaljerna?

A ☐ B ☐ A och B är likvärdiga ☐

Förklara varför det är lättast att urskilja detaljerna i just denna utformning:

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Evacuation Research at LU

Examples of recent and ongoing evacuation research projects

Project name	Year	Sponsor	Total budget
CascEff	2014-2017	EU-FP7	€ 3.6 millions
Evacuation Route Design	2013-2015	Trafikverket	€ 300K
Ascending stair evacuation	2013-2015	Trafikverket/Brandforsk	€ 230K
KESÖ	2010-2013	EU-Interreg	€ 1 million
METRO	2009-2012	Multiple Swedish agencies	€ 1.4 million

More info at www.brand.lth.se

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Evacuation modelling

Why do we use evacuation models in FSE?

- Calculation of evacuation time for engineering analysis (RSET/ASET)
- Prediction of human behaviour

DATA ↔ **THEORY**

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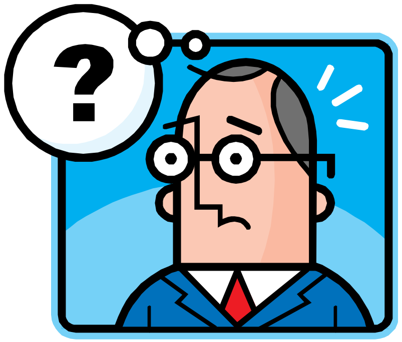
Evacuation modelling

The lost users



60+ models

List of models

1. AENEAS
2. ALLSAFE
3. ASERI
4. BFires V1 / BFires-II
5. BGRAF
6. BuildGEM
7. BUMMPEE
8. Cube Avenue
9. CRISP
10. DBES (Distributed Building Evacuation Simulat
11. EARM
12. EESCAPE
13. EGRESS
14. Egress Complexity Model
15. EgressPro
16. ENTROPY
17. EPT (Evacuation Planning Tool)
18. E-Scape
19. ESM
20. EVACNET4 / EVACNET+
21. EVACSIM
22. EvacuationNZ
23. Evi
24. EXIT89
25. EXITT
26. Exodus
27. F.A.S.T
28. FDS+Evac
29. FIRECAM
30. Firescap
31. FlowTech
32. FPETool
33. GridFlow
34. Helios
35. Legion
36. MA&D (Micro Analysis & Design)
37. Magnetic Model
38. MASCM
39. MASSEgress
40. MASSIVE Software
41. MASSMotion
42. Myriad II
43. Nomad
44. PathFinder
45. PEDFLOW
46. Pedestrian Dynamics
47. PedGo
48. PedRoute / Paxport
49. PedSim
50. S-Cape (external PDF)
51. SGEM
52. SimPed
53. Simulex
54. SimWalk
55. SMART Move
56. SpaceSensor
57. STEPS
58. Takahashi's Fluid Model
59. TIMTEX
60. TSEA: Transient Simplified Egress Analysis
61. UAF (Urban Analytical Framework)
62. VISSIM
63. WayOut
64. ZET

Evacmod.net
Evacuation Modelling Portal

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Evacuation modelling

Evacuation models

Accessibility (GUI, default settings, transparency)
Capabilities/limitations

Applications

Modelling different behaviours (Exit choice, human-fire interaction, etc.)

Accuracy of results

Verification and Validation, Uncertainty

Selection of the appropriate model(s) for the scenarios of interest

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Evacuation modelling

Evacuation modelling portal made by the evacuation modelling community FOR the evacuation modelling community

INDEPENDENT (No political or commercial bias, no profit)

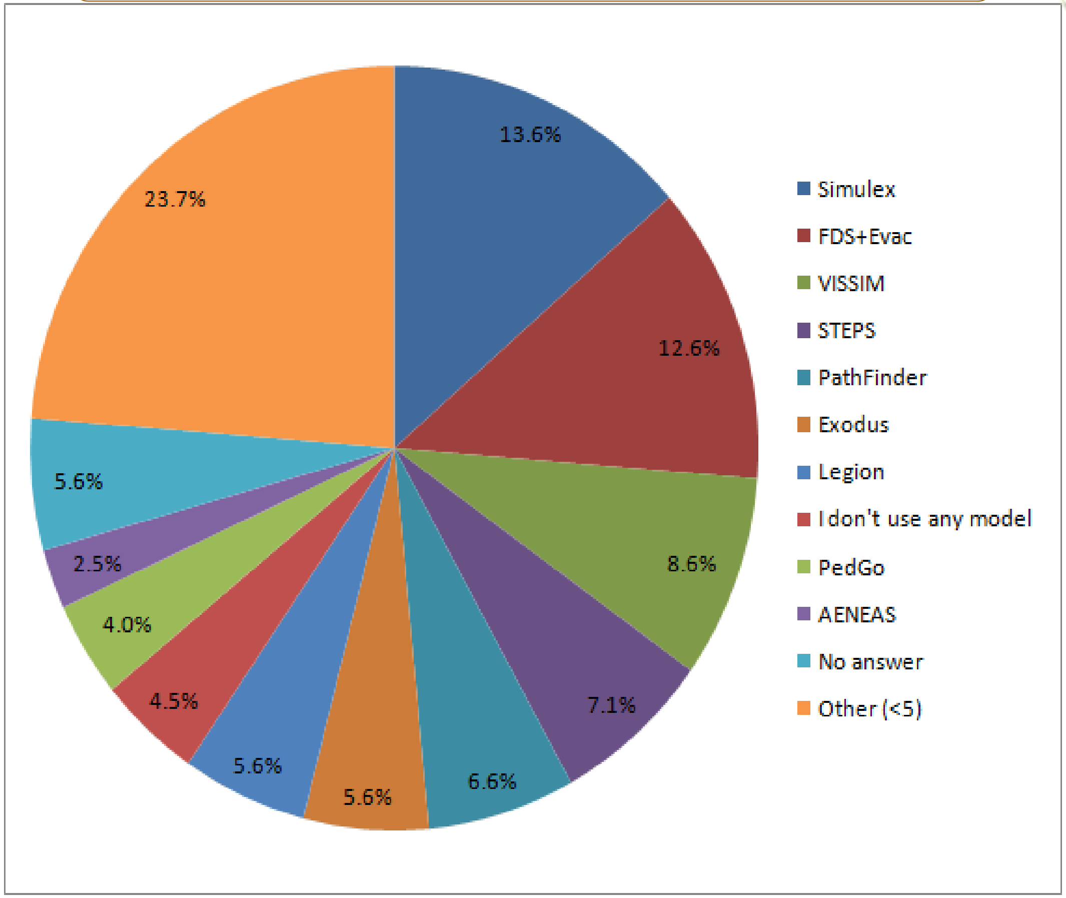
DIFFERENT USERS (students, fire safety engineers, software engineers, behavioural scientists, researchers, etc.)

SECTIONS (Literature with over 3000 references, forum, events, etc.)

SURVEY ON EVACUATION MODELS

Evacuation modelling

Most used models



Ronchi E & Kinsey M (2011). Evacuation models of the future. Insights from an online survey on user's experiences and needs. In Proceedings of EVAC11, Santander (Spain)

Evacuation modelling

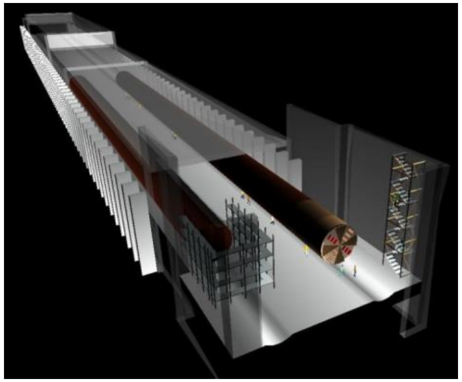
LU expertise on evacuation modelling

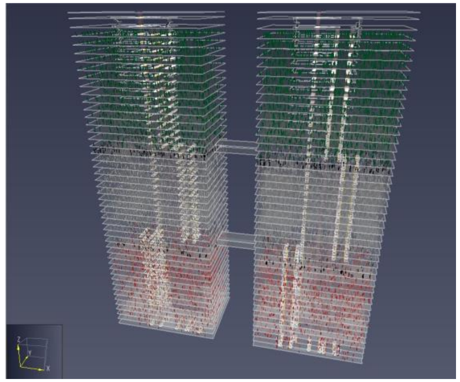
Expertise in the most known commercial and research models:

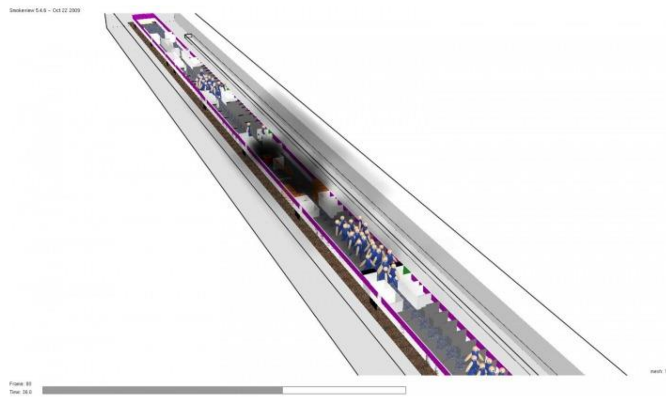
- STEPS (MottMacdonald)
- Simulex (IES)
- Pathfinder (Thunderhead Eng)

- FDS+Evac (VTT)
- Gridflow (BRE)
- Exit89 (NFPA)

- CrowdControl (Siemens)
- Viswalk (PTV)
- Legion (Legion Ltd)
- MassMotion (Arup)







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Evacuation modelling

Review of selected models

Simulation of different behaviours in underground facilities

FDS+Evac
buildingEXODUS
Pathfinder
STEPS
Simulex

Most known models (Top 5)

www.Evacmod.net model directory (Ronchi & Kinsey, 2011)
Ronchi E (2013). Testing the predictive capabilities of evacuation models for road tunnel safety analysis. Safety Science Volume 59, pp.141-153

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Evacuation modelling

Which variables are important in the evacuation simulation of underground facilities?

- People movement in space (coarse network/ fine network /continuous model / hybrid)?
- Impact of smoke on human behaviour?
- Has the model been tested/validated specifically for certain evacuation scenarios?

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Evacuation modelling

Fire-human interaction

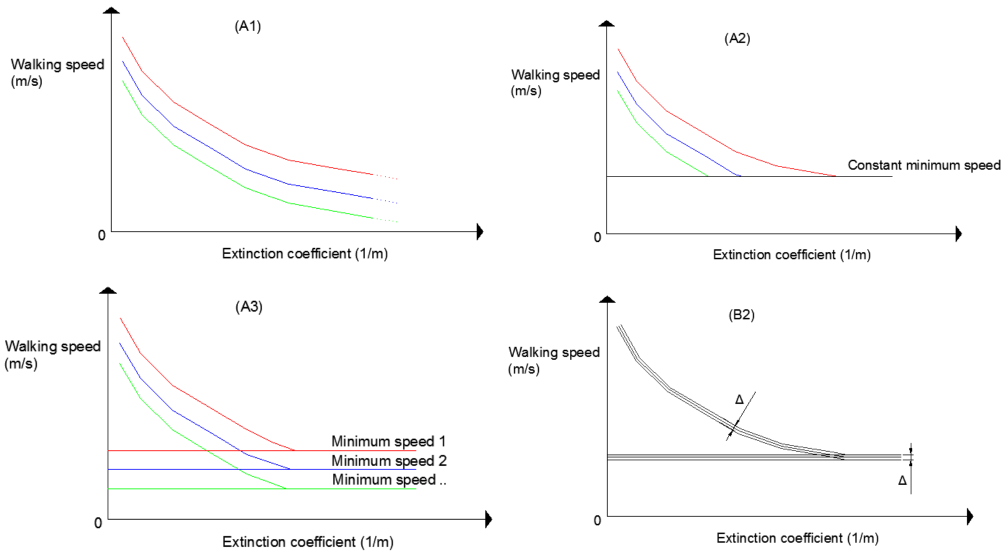
How the evacuation model represents the interactions between fire and agents' behaviour

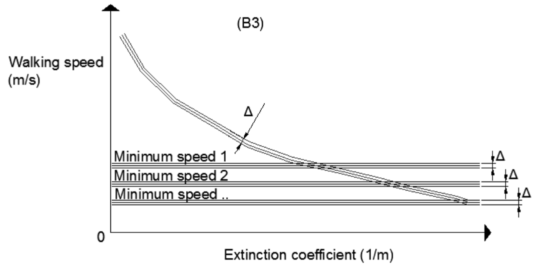
- Importing output from fire models
- FED
- Smoke impact on walking speed
- Smoke impact on exit choice

Evacuation modelling

How does smoke affect walking speeds?

(Ronchi et al, 2012)





$$v_i^s = v_i^0 c(K_s)$$

$$v_i^s = Max\{v_{i,min}, v_i^0 c(K_s)\}$$

$$v_i^s = Max\{v_{i,min}(i), v_i^0 c(K_s)\}$$

$$v_i^s = Max\{v_{i,min}, v_i(K_s) \pm \Delta\}$$

$$v_i^s = Max\{v_{i,min}(i), v_i(K_s) \pm \Delta\}$$

Ronchi, E., Gwynne, S.M.V., Purser, D.A., Colonna, P., 2013. Representation of the Impact of Smoke on Agent Walking Speeds in Evacuation Models. Fire Technol 49, 411–431. doi:10.1007/s10694-012-0280-y

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Evacuation modelling

FDS+Evac

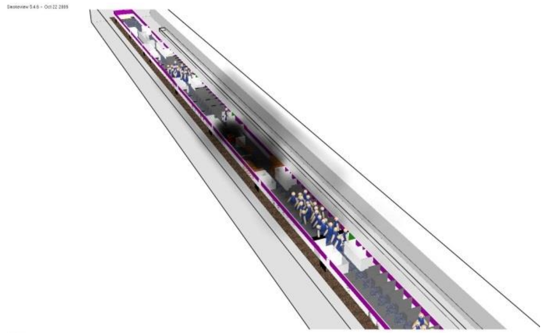
Version 2.5.0 in FDS6

Grid/structure

Continuous model based on social force model

Exit choice

Optimal, conditional, user defined



V&V

IMO tests + case studies on buildings, stations, tunnels, etc.

Fire-human interaction

Smoke affects exit choice and speed. Fractional and absolute speed reduction based on both F&N, Jin and custom. FED can be calculated.

Evacuation modelling

FDS+Evac

Advantages	Limitations
- Transparency (Open source) - Support from the community - Complex scenarios can be modelled - Advanced sub-models - Group interactions (leaders-followers) - Direct interaction with fire (FDS) - Constant development - Significant quantity of research studies available for reference - Free	- Model input set up is time consuming (no free GUI) - Not easy to use for complex scenarios - Computationally expensive - Only partial documentation for the newest version embedded in FDS6

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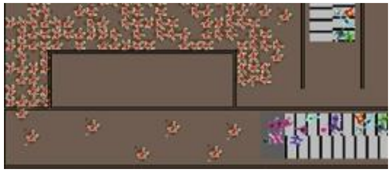
Evacuation modelling

buildingEXODUS

Version 6.1

Grid/structure
Fine Network and hybrid



Exit choice
Optimal, conditional, shortest, user defined

V&V
IMO tests + case studies on buildings, ships, aircrafts, stations, etc.

Fire-human interaction
Smoke affects exit choice and speed. Fractional reduction based on Jin in v5.0, a curve with both Jin and F&N in later versions.
FED can be calculated.

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Evacuation modelling

buildingEXODUS

Advantages

-Fast computational time (with fine network approach)
-Complex scenarios can be modelled
- Advanced sub-models
- Direct interaction with a fire model (Smartfire)
- Constant development
- Significant quantity of research studies available for reference

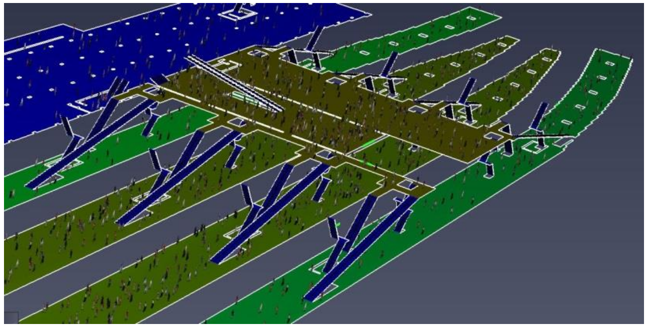
Limitations

- Closed source
- Limitation of CA models
- No user support (only developer support)
- Expensive

Evacuation modelling

Pathfinder

Version 2015



Grid/structure
Continuous based on Steering behaviours

Exit choice
Optimal, shortest, user defined

V&V
IMO tests, case studies (including buildings, tunnels, etc.), NIST Tech Note 1822

Fire-human interaction
No direct fire-human interaction, only visual representation of slices (e.g. visibility, temperature, etc.)

Evacuation modelling

Pathfinder

Advantages	Limitations
- Fast model input set up - It easily permits to simulate complex buildings - One of the most used models (user and developer support) - Constant development	- No access to the source code (commercial software) - no direct fire-human interaction - No advance sub-model for exit choice in smoke - Relative new model, not many research studies available for reference

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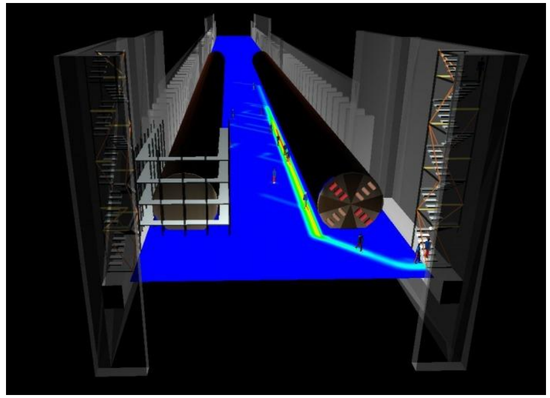
Evacuation modelling

STEPS

Version 5.3



Grid/structure

Fine Network

Exit choice

Conditional

V&V

against NFPA 130 and case studies for buildings, stations, etc.

Fire-human interaction

Smoke affects speed. Absolute reduction of speed based on Jin by default (or custom). FED data can be imported.

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Evacuation modelling

STEPS

Advantages	Limitations
- It permits to simulate complex buildings - One of the most used commercial models - Direct interaction with fire output (e.g., FDS, CFAST) - Constant development - Significant quantity of case studies available for reference	- No access to the source code (commercial software) - No complex modelling of exit choice in smoke - Limitations of CA models - No users' support (only developer)

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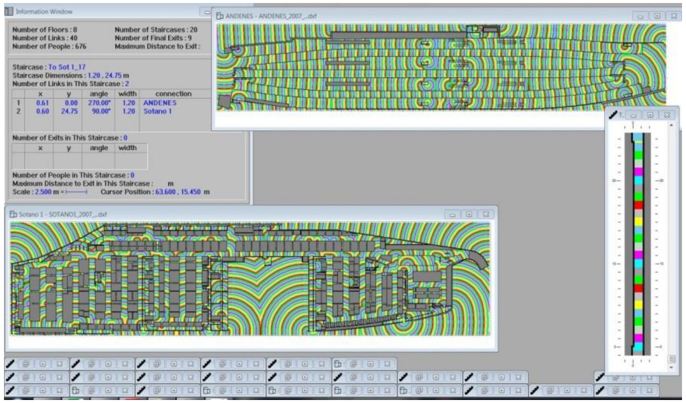
Evacuation modelling

Simulex



Version 6.0

Grid/structure
Continuous

Exit choice
Shortest or user defined (based on distance maps)

V&V
IMO tests and case studies (mostly for buildings)

Fire-human interaction
No direct impact of smoke on agent behaviours.

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Evacuation modelling

Simulex

Advantages	Limitations
- Fast model input set up - One of the most used models - Fast computational time - Significant quantity of case studies available for reference	- No user support (only developer) - No access to the source code (commercial software) - No direct fire-human interaction - No advanced sub-model for exit choice in smoke

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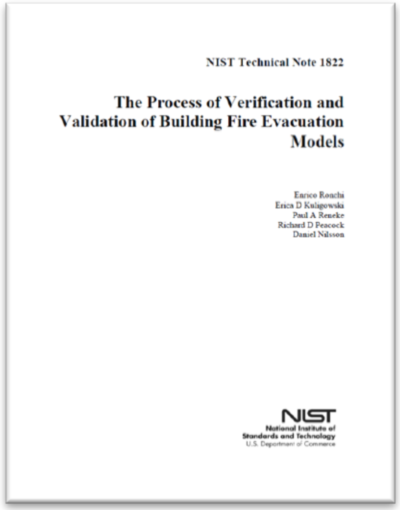
Verification and Validation

Extensive expertise on evacuation model V&V

Joint effort between NIST and LU

Ronchi, E., Kuligowski, E.D., Reneke, P.A., Peacock, R.D., Nilsson, D., (2013). *The process of Verification and Validation of building fire evacuation models*. National Institute of Standards and Technology. Technical Note 1822.


NIST Technical Note 1822

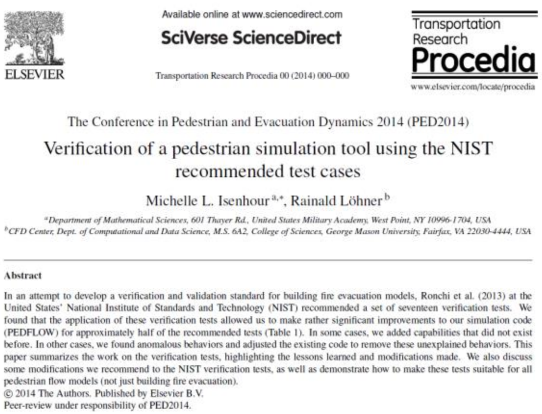
The Process of Verification and Validation of Building Fire Evacuation Models

Enrico Ronchi
Erica D Kuligowski
Paul A Reneke
Richard D Peacock
Daniel Nilsson

NIST
National Institute of Standards and Technology
U.S. Department of Commerce

Verification and Validation

- Tech Note 1822 used by model developers and testers
- ISO standards development (TC92/SC4/WG7)
- Used by many model developers in the USA (Pathfinder, PEDFLOW), Japan (SimTread), Germany (VISWALK, OpenPedSim), Poland and UK (MassMotion)


Available online at www.sciencedirect.com
SciVerse ScienceDirect
Transportation Research Procedia 00 (2014) 000–000
ELSEVIER
Transportation Research Procedia
www.elsevier.com/locate/procedia

The Conference in Pedestrian and Evacuation Dynamics 2014 (PED2014)

Verification of a pedestrian simulation tool using the NIST recommended test cases

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[b]CFD Center, Dept. of Computational and Data Science, M.S. 6A2, College of Sciences, George Mason University, Fairfax, VA 22030-4444, USA

Abstract

In an attempt to develop a verification and validation standard for building fire evacuation models, Ronchi et al. (2013) at the United States' National Institute of Standards and Technology (NIST) recommended a set of seventeen verification tests. We found that the application of these verification tests allowed us to make rather significant improvements to our simulation code (PEDFLOW) for approximately half of the recommended tests (Table 1). In some cases, we added capabilities that did not exist before. In other cases, we found anomalous behaviors and adjusted the existing code to remove these unexplained behaviors. This paper summarizes the work on the verification tests, highlighting the lessons learned and modifications made. We also discuss some modifications we recommend to the NIST verification tests, as well as demonstrate how to make these tests suitable for all pedestrian flow models (not just building fire evacuation).
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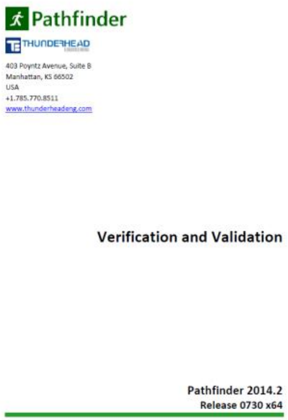
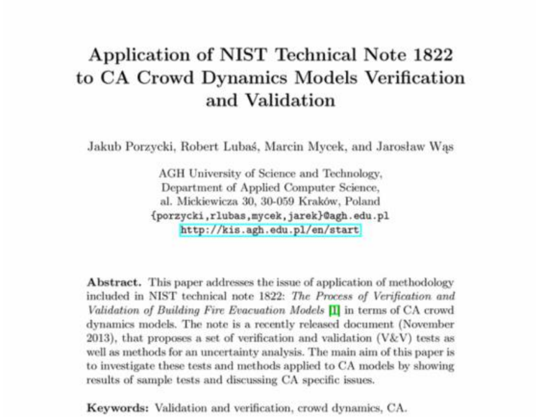
Peer-review under responsibility of PED2014.


Pathfinder
THUNDERHEAD
403 Poyntz Avenue, Suite B
Manhattan, KS 66502
USA
+1.785.770.8511
www.thunderheadeng.com

Verification and Validation

Pathfinder 2014.2
Release 0730 x64


Application of NIST Technical Note 1822 to CA Crowd Dynamics Models Verification and Validation

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Abstract. This paper addresses the issue of application of methodology included in NIST technical note 1822: *The Process of Verification and Validation of Building Fire Evacuation Models* [1] in terms of CA crowd dynamics models. The note is a recently released document (November 2013), that proposes a set of verification and validation (V&V) tests as well as methods for an uncertainty analysis. The main aim of this paper is to investigate these tests and methods applied to CA models by showing results of sample tests and discussing CA specific issues.

Keywords: Validation and verification, crowd dynamics, CA.

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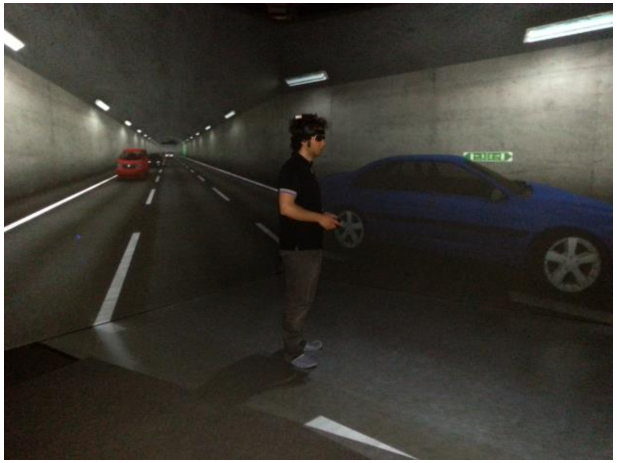
Virtual Reality

Evacuation behaviour in immersive VR lab experiments (CAVE)



Virtual Reality

VR experiments

- Way-finding
- Refuge chambers
- System design

Ronchi, E., Nilsson, D., Kojić, S., Eriksson, J., Lovreglio, R., Modig, H., Walter, A.L., 2015. A Virtual Reality Experiment on Flashing Lights at Emergency Exit Portals for Road Tunnel Evacuation. Fire Technology. doi:10.1007/s10694-015-0462-5

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Virtual Reality

VR experiments

Oculus rift

Affordance-based evaluation of different systems

Cosma, G., 2014. Virtual reality experiments on the impact of way-finding lighting systems on egress from smoke-filled railway tunnel (No. 5455). Lund University, Lund, Sweden.

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THANK YOU!

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Department of Fire Safety Engineering: **www.brand.lth.se**
Evacuation modelling portal: **www.evacmod.net**

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References

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