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VR PLATFORM TO IMPROVE FIRE EVACUATION

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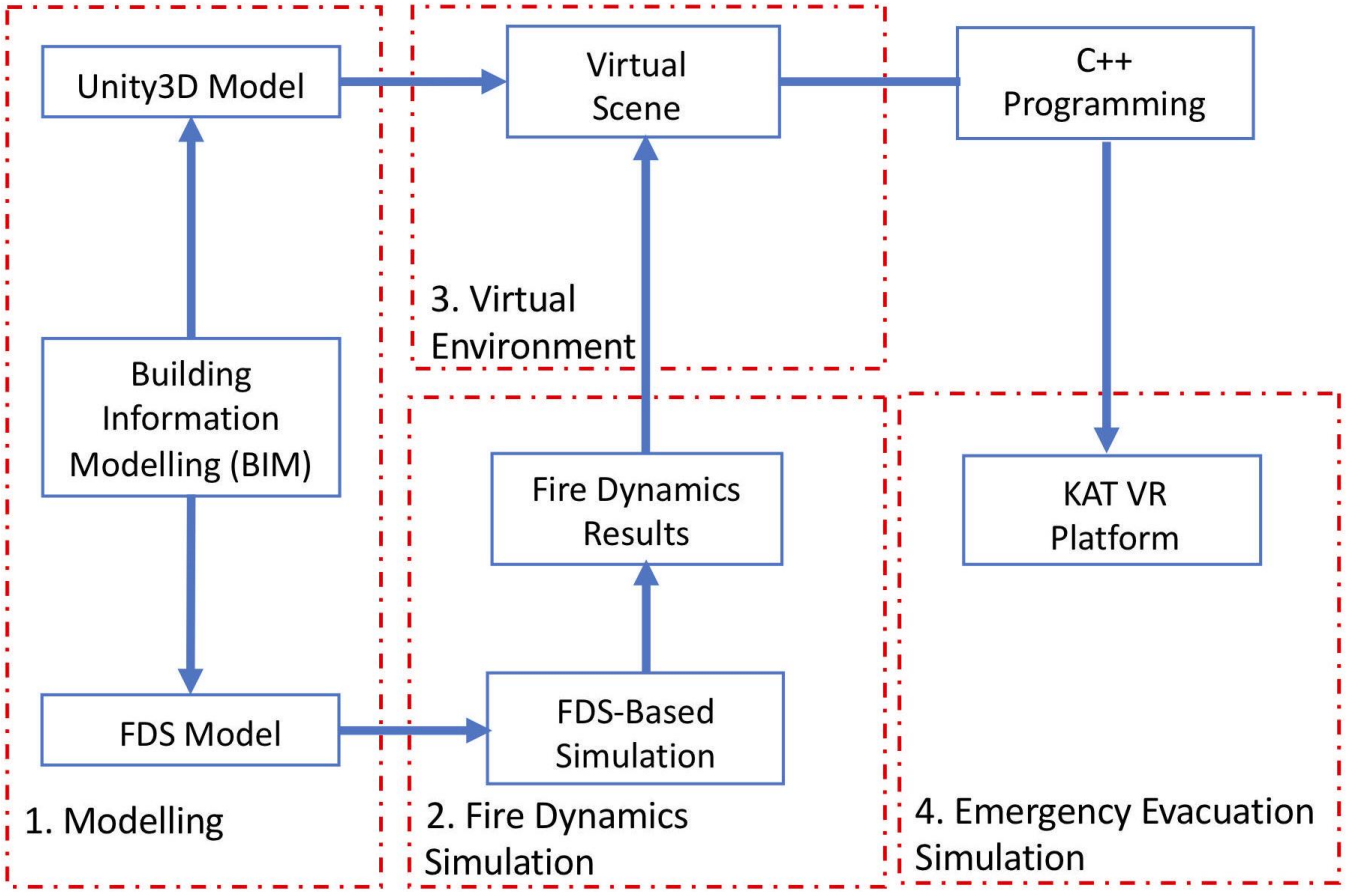
Objectives

- **Training platform** → to **improve humans' abilities** in emergency conditions for **evacuation and SAR**
- **Public buildings** such as **schools** with a number of occupants, both users and operators
- **Large scale**
- To improve **community resilience**

SYSTEM ARCHITECTURE

1. BIM → Unity & FDS;
2. FDS output → VR;
3. VR → KAT VR Platform;
4. VR and Emergency Simulation: training



SIMULATION OF FIRE SCENARIO (FDS)

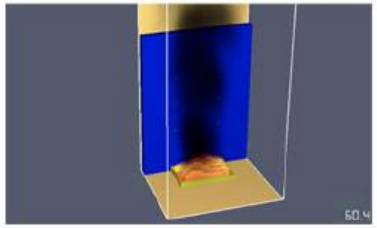
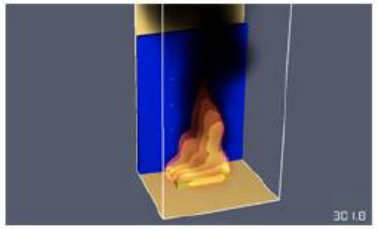
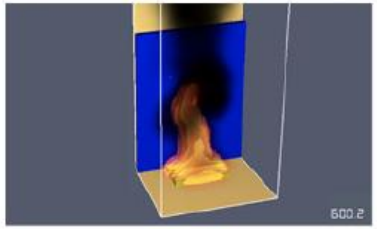
- **FDS** is a **fluidynamic** code from **NIST** to compute fire scenarios
- **FDS forecasts flow velocities and temperatures** by dividing the space into **discrete volumes**
- **Mesh**: creating a space that contains all the geometry of the system divided by **cubic-shaped elements**
- Definition of **material** and **thermal properties**
- **Flow-type boundary conditions**: free, none, …
- **Wind direction and intensity**

FDS evaluation: comparison with physical test

- "Experimental investigations of the fire behavior of facades with EPS exposed to different fire loads" - **Northe et al. 2016**
- **Fire tests on a flat facade** with an **external insulation in polystyrene**
- 6 m wide x 8 m high wall, 300 mm thick
- **Ignition point** on the ground is inside a **steel pan** (1.30m × 2.80m × 0.31 m) with a volume of 200 l (**isopropanol fuel**)

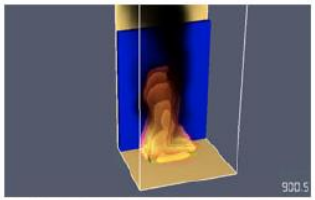
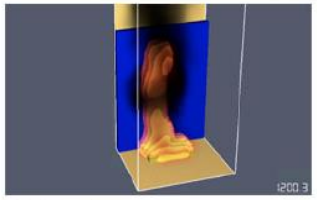
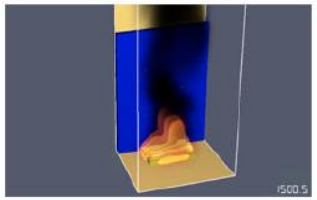
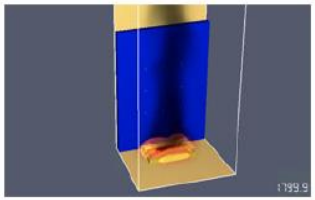
FDS evaluation: comparison with physical test

(FDS) (Northe et al. 2016)

	Simulation	Real test
1 min		
5 min		
10 min		

FDS evaluation: comparison with physical test

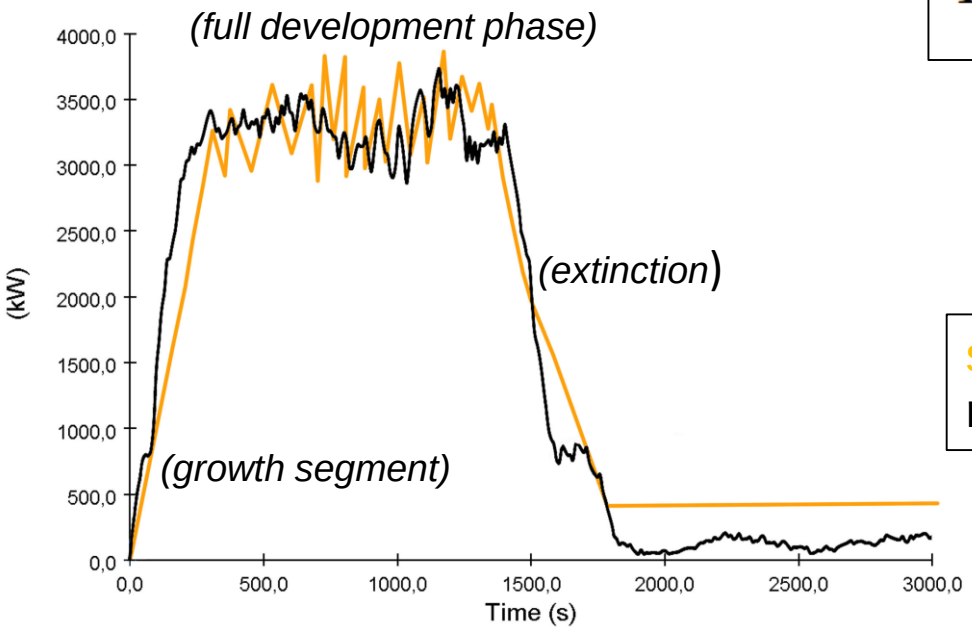
(FDS) (Northe et al. 2016)

	Simulation	Real test
15 min		
20 min		
25 min		
30 min		

FDS evaluation: comparison with physical test

- Heat Release Rate (HRR - released energy)
- Maximum value of HRR can be estimated using Eurocode 1-Annex E

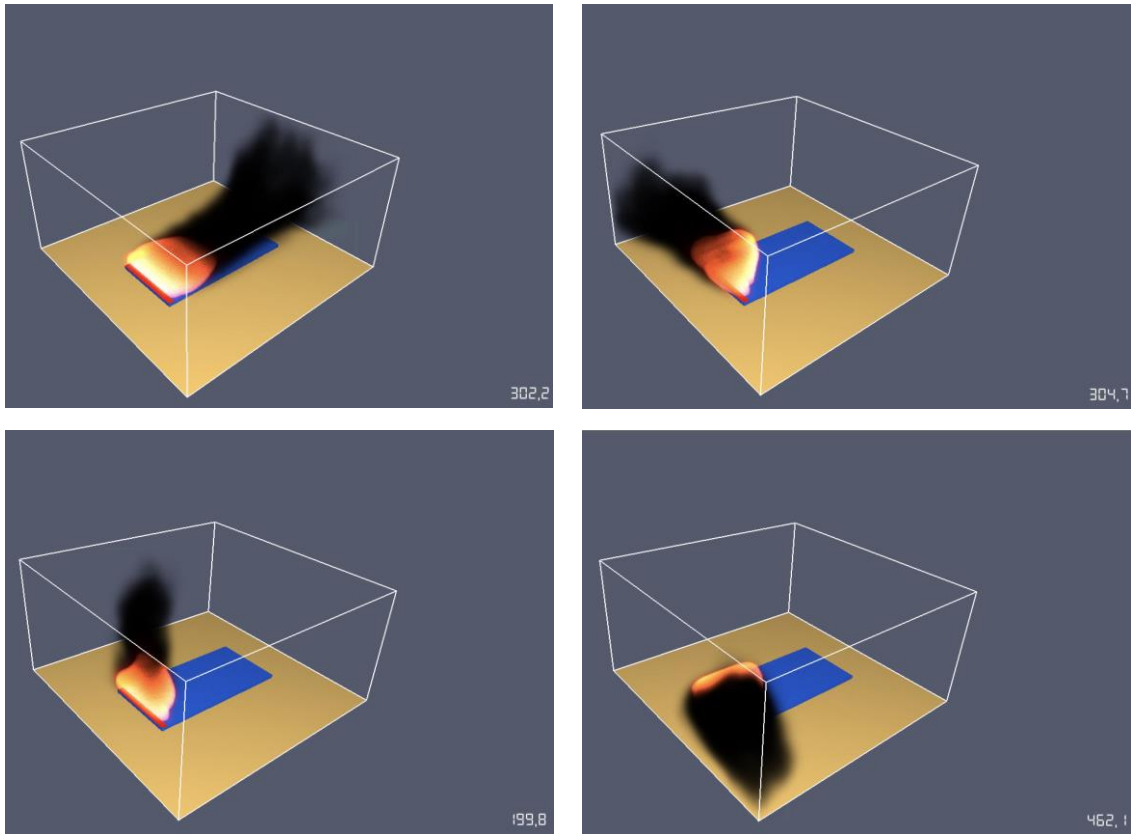
$$HRR_{max} = 0,10 m H A_v h_{eq}^{0.5}$$



simulation
real fire test

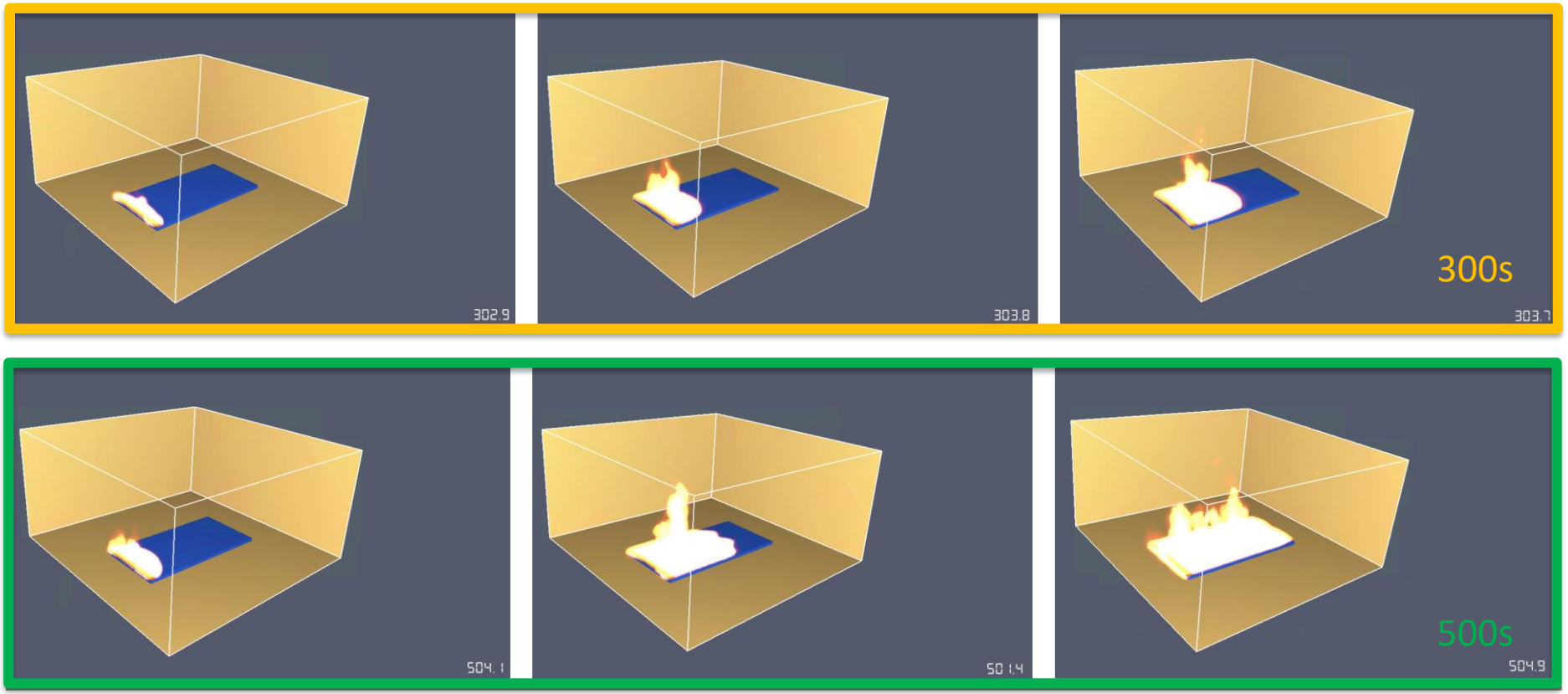
FDS small scale tests : wind

- E.g. direction
- But also:
- Intensity
- Dynamic



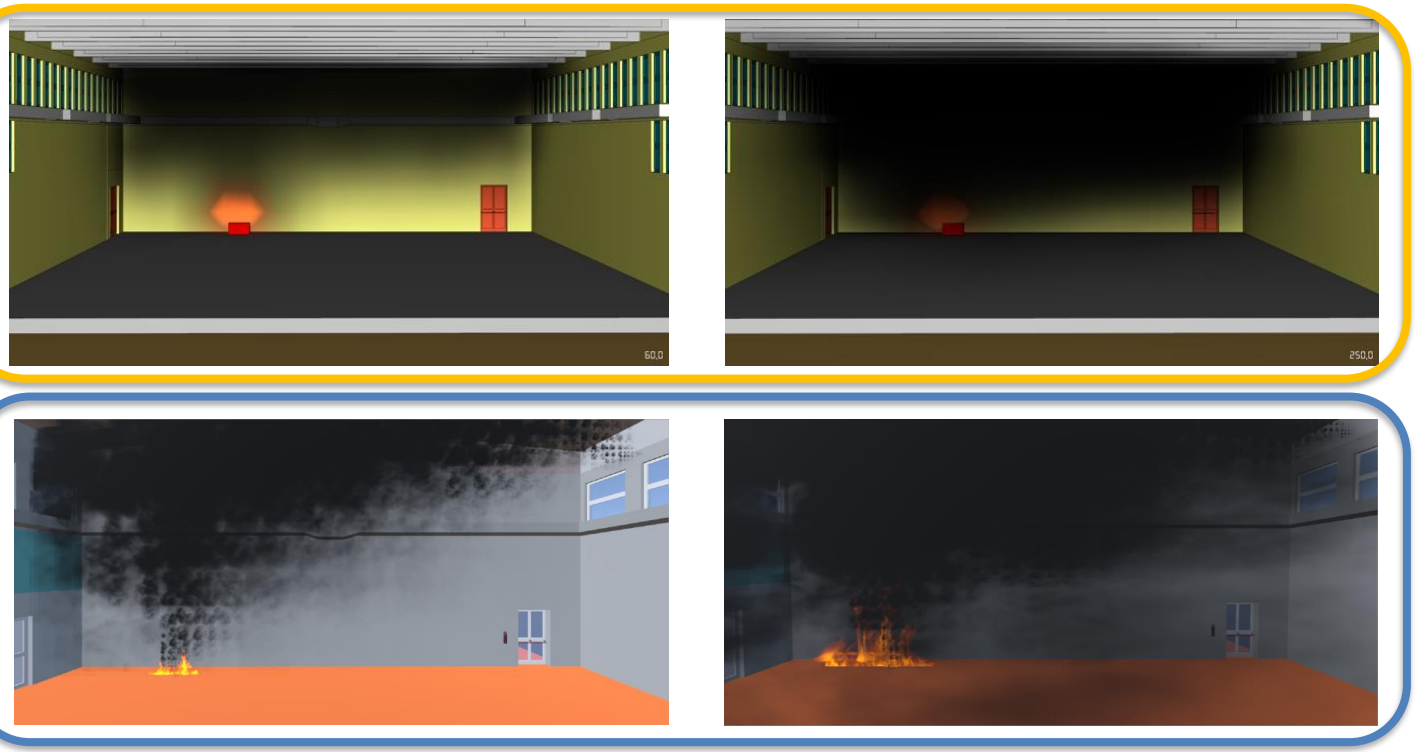
FDS small scale tests : materials

- Concrete → no fire propagation
- PVC, wood → different propagation levels



FIRE SCENARIO (FDS) → VR

FDS output data are integrated with the VR model in order to reproduce a **realistic** fire scenario



VR FIRE SIMULATION

- **FDS results are imported into the Unity3D model and the VR platform** → virtual reality simulation → **C++ plugin script**
- **VR Headset sensor** allows the user to be **immersed** inside the virtual scenario
- Navigation is controlled by **shoe cover sensors**

VR FIRE SIMULATION

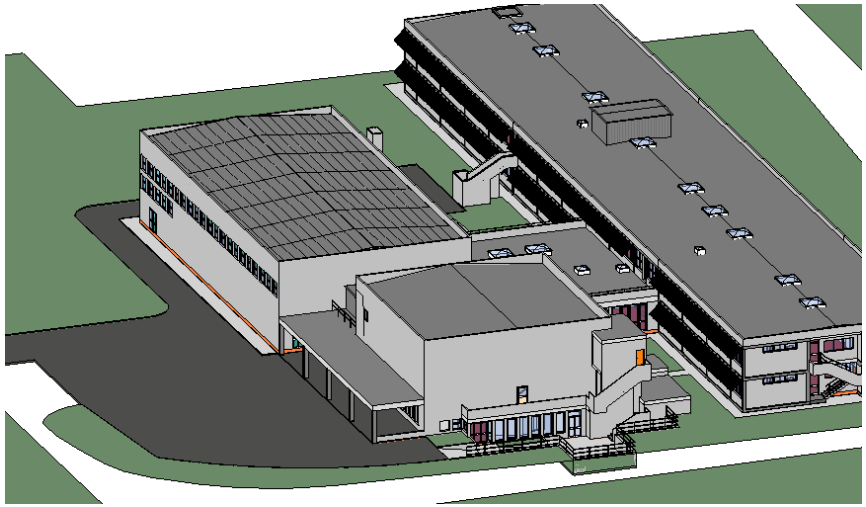
- In Unity 3D **fire and smoke are finished with the particles system → particle emitter-animator-renderer**
- Particle **collider is added to walls → reflecting fire and smokes**

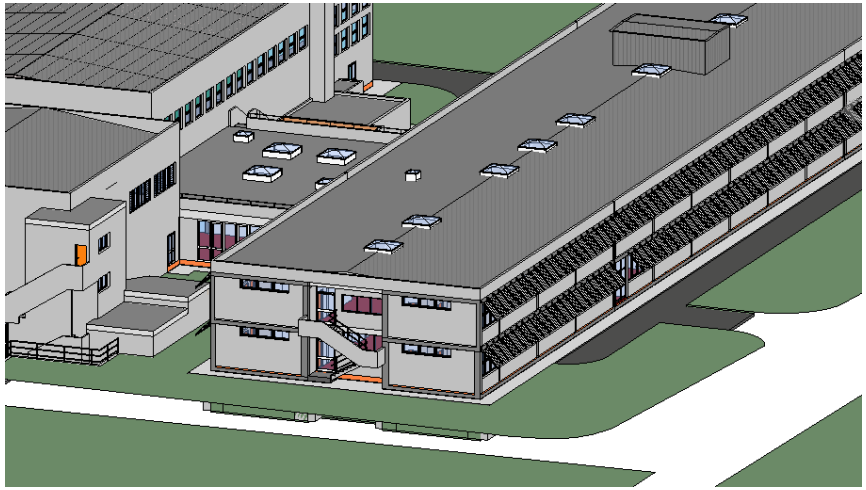
Indoor volume is filled by smoke particles

Building scale
School case study

"Mascagni" High School

BIM (Building Information Management)





Built in Melzo (MI) in '70s:

- Classrooms and Laboratories;
- Canteen and Auditorium;
- Gym.

From BIM to Virtual Reality (VR)

REVIT → UNITY

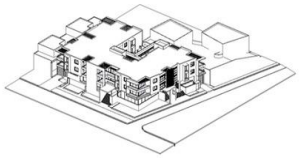
DATA COLLECTION

STRUCTURAL MODEL

ARCHITECTURAL MODEL

MEP MODEL

AUTODESK® REVIT®

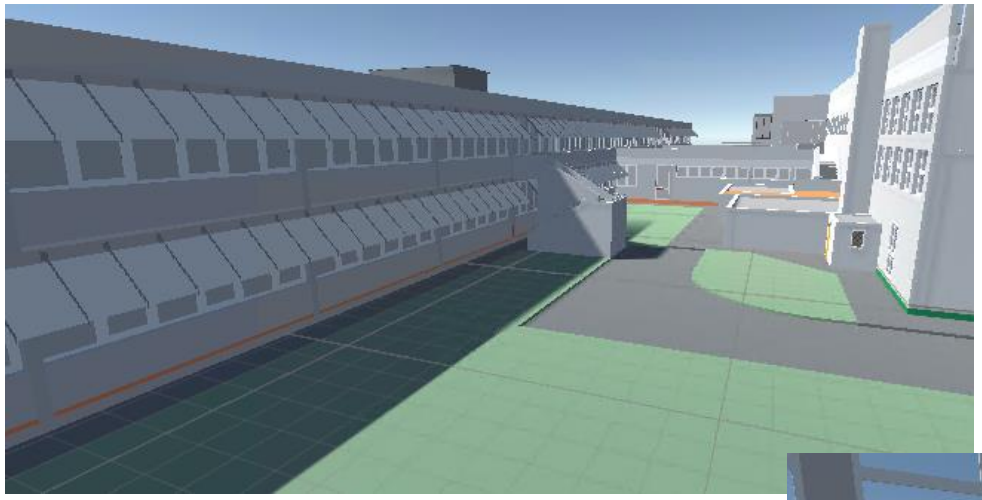


EXPORTING FBX

Game Integrated Development Environment

unity

UNITY for VR



UNITY for VR

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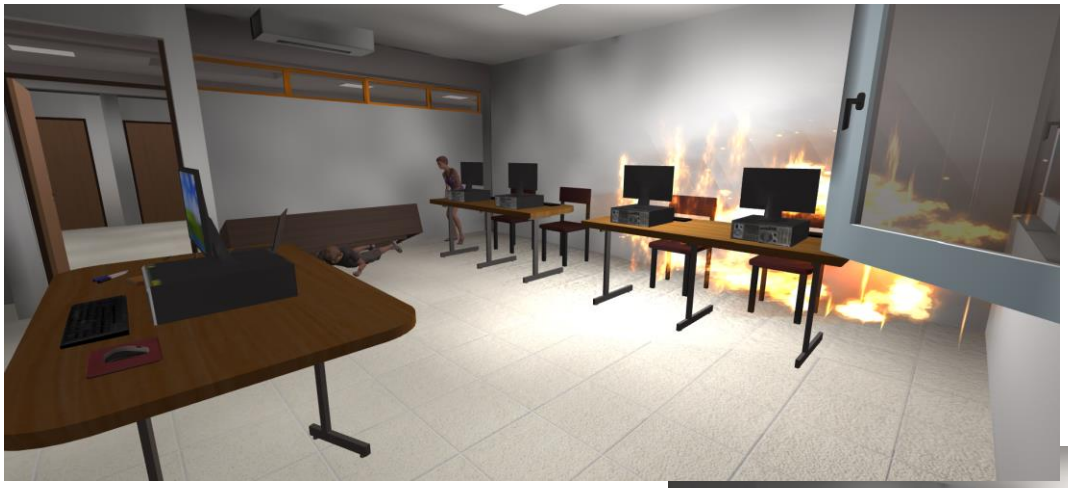


VR platform implementation

Further developments

- **Next step will include occupants**
  - Students
  - Victims
  - Rescuers e.g. firefighters

- **To test a training procedure in multi-steps**

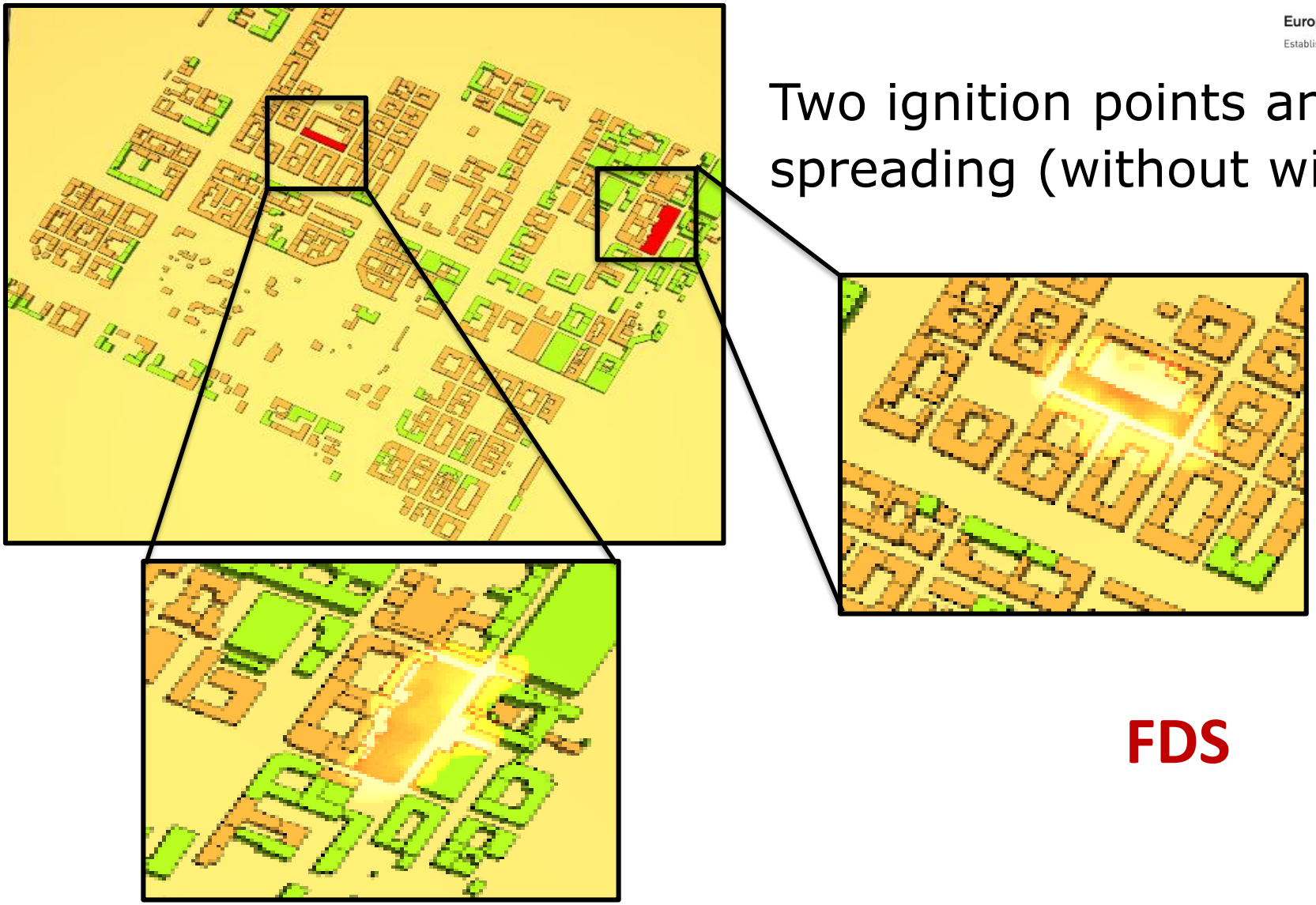
Trainig procedure

- Considering **e.g. FFE** on the **first floor** of the school
- In the **computer room** and **spread to the nearby library** because of a **wall collapsing, causing injuries**
- **The procedure as follows:**

1 - Occupants start to evacuate by them self
2 - Firefighter intervention
3 - Using stairs instead of elevator
4 - Rescue of injured people
4 – Use of hydrants and extinguishers

Large scale
"IdealCity" case study

SIMULATION OF FFE AT URBAN SCALE



Two ignition points and fire spreading (without wind)

FDS

SIMULATION OF FFE AT URBAN SCALE

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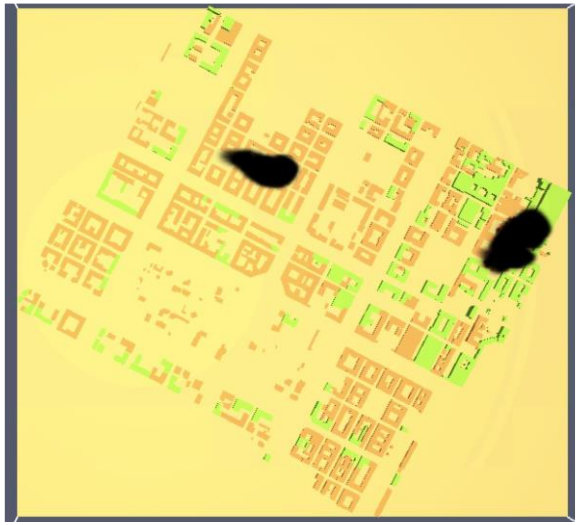
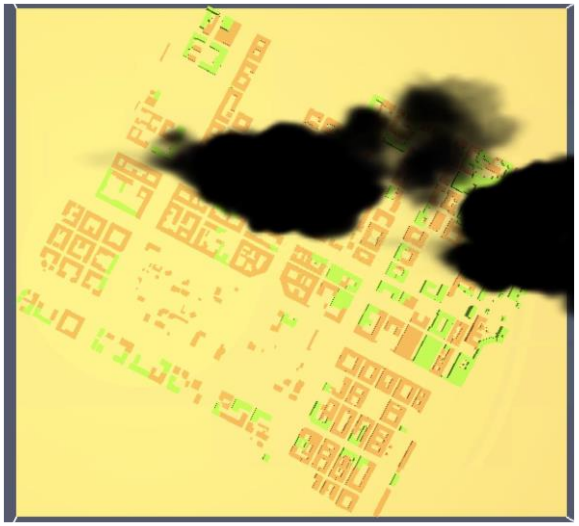
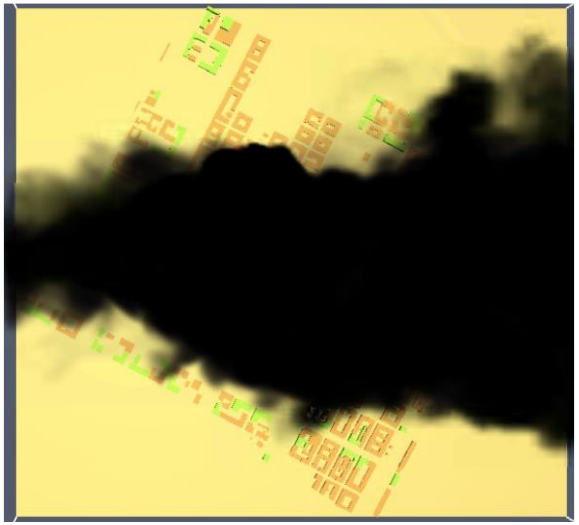
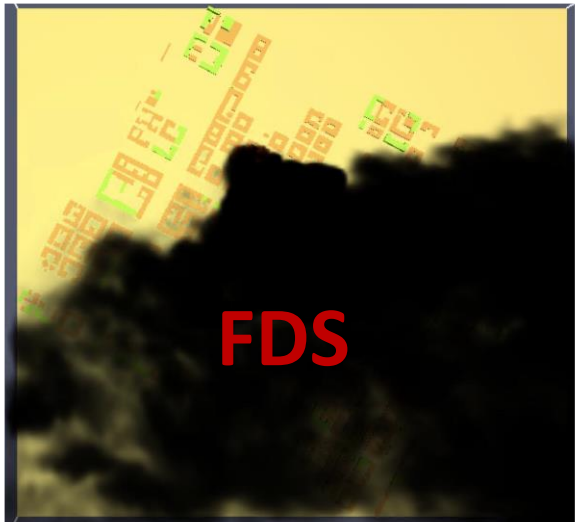


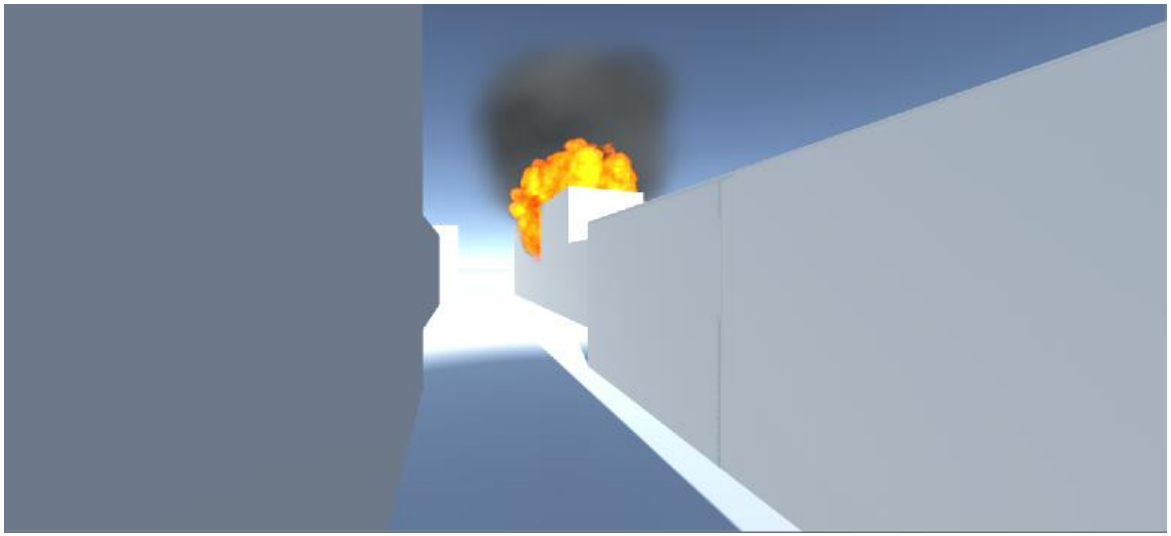


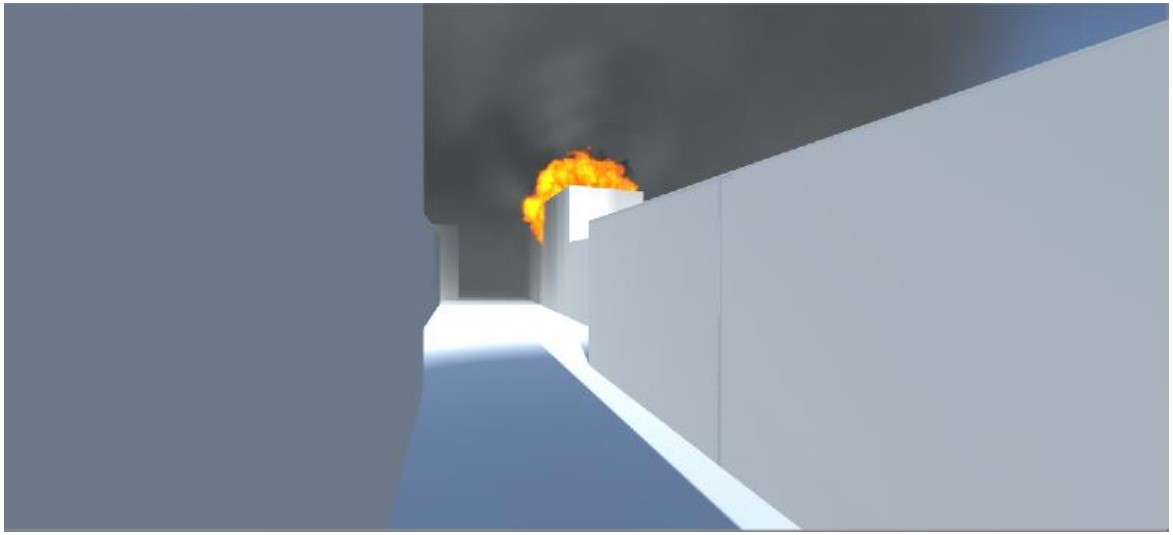
Smoke and
wind action





VR SIMULATION OF FFE AT URBAN SCALE

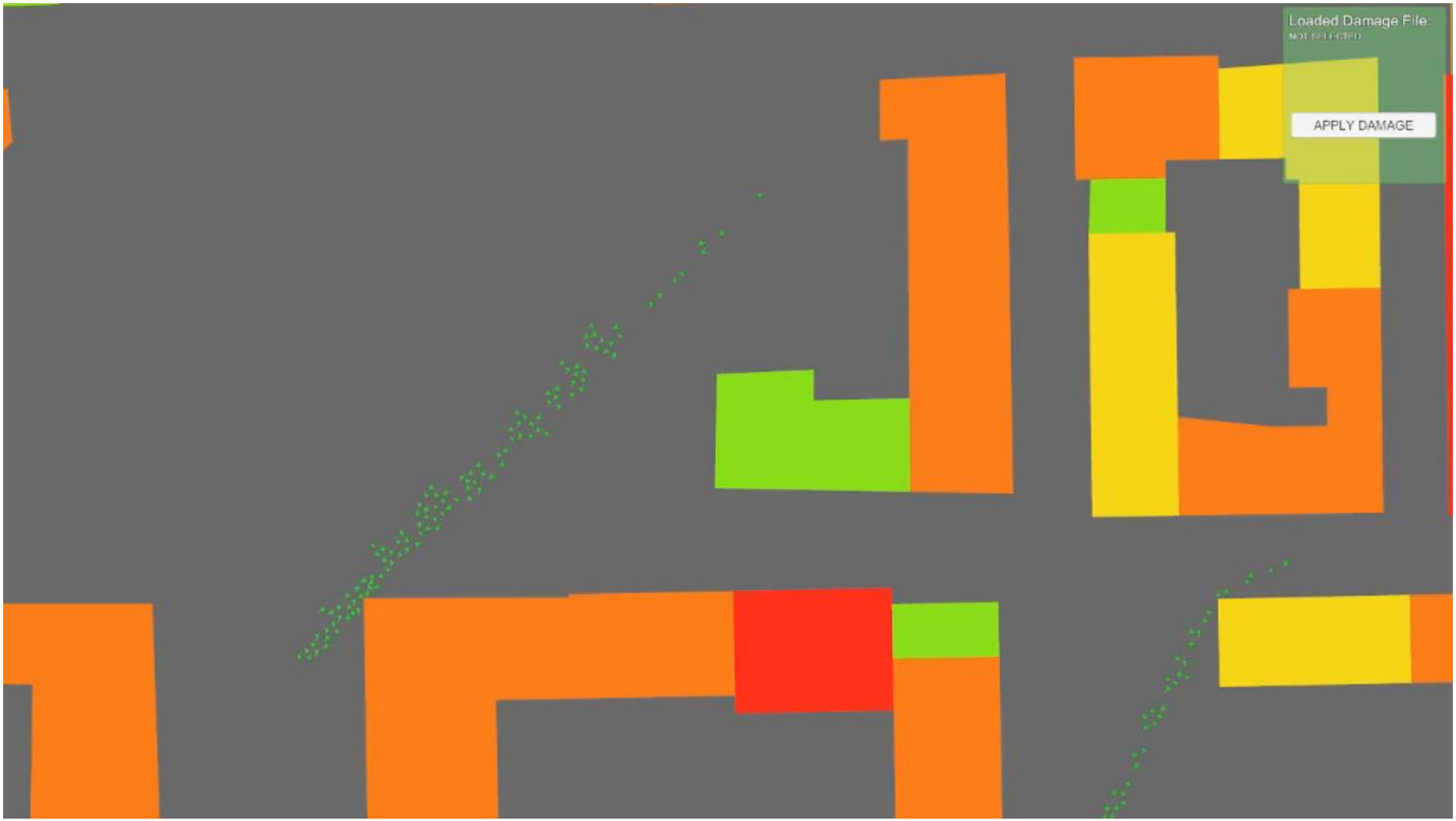




FDS → UNITY3D

ABM model of evacuation

(damages, debris road interruption)



Test of AEM application

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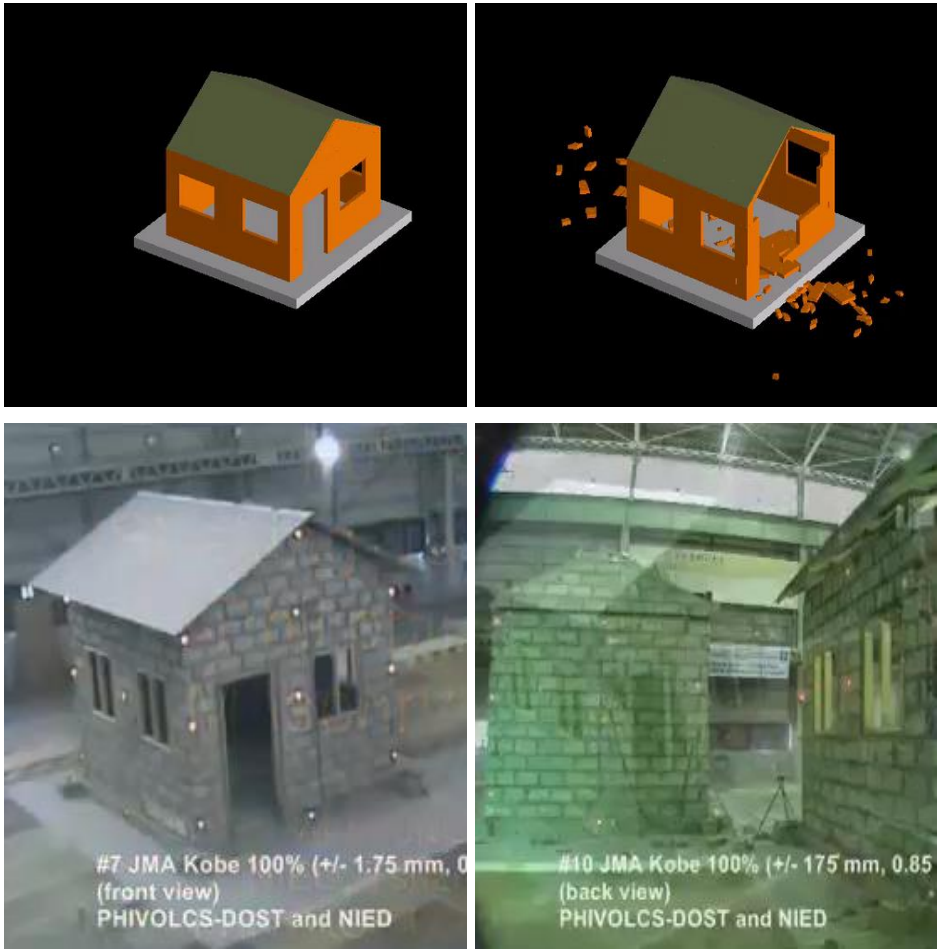
Kobe 100% Kobe 110%



National Research Institute for Earth Science and Disaster Prevention (NIED-JP)

Formula to assess debris extension for masonry

European Research Council
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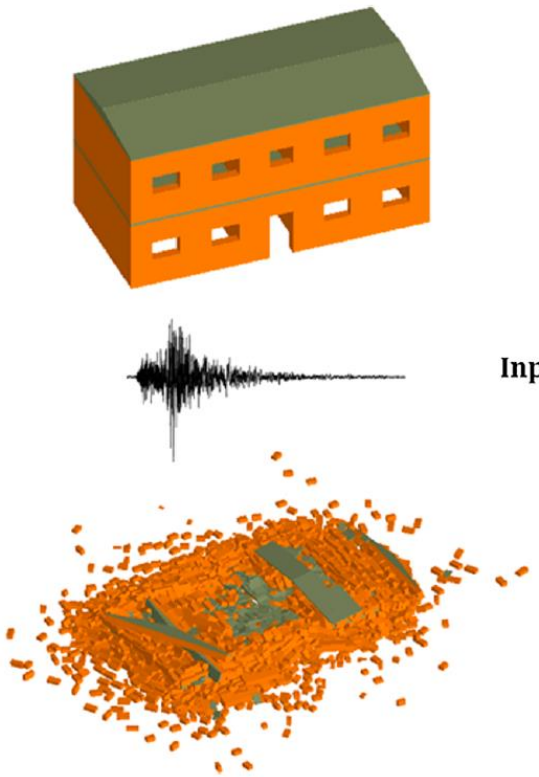
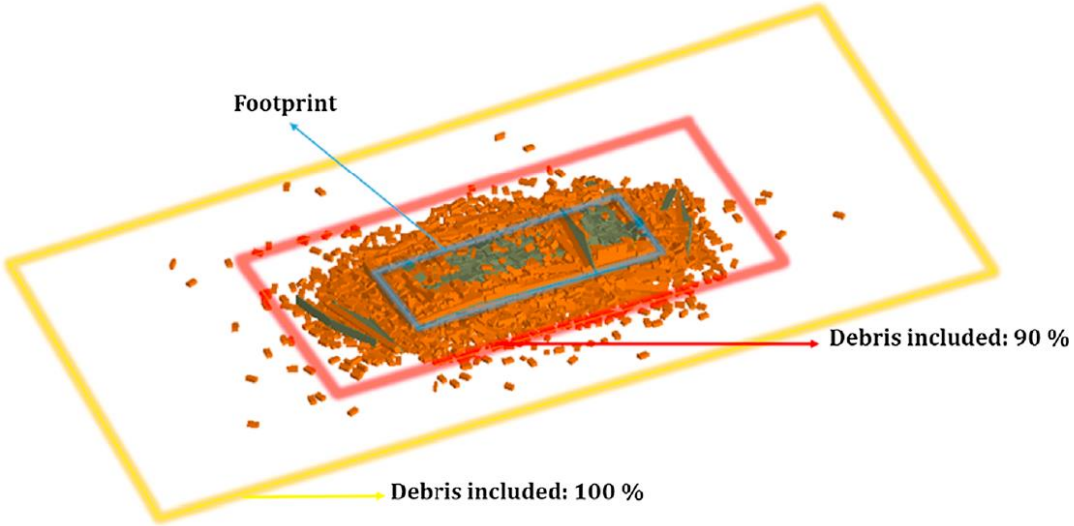


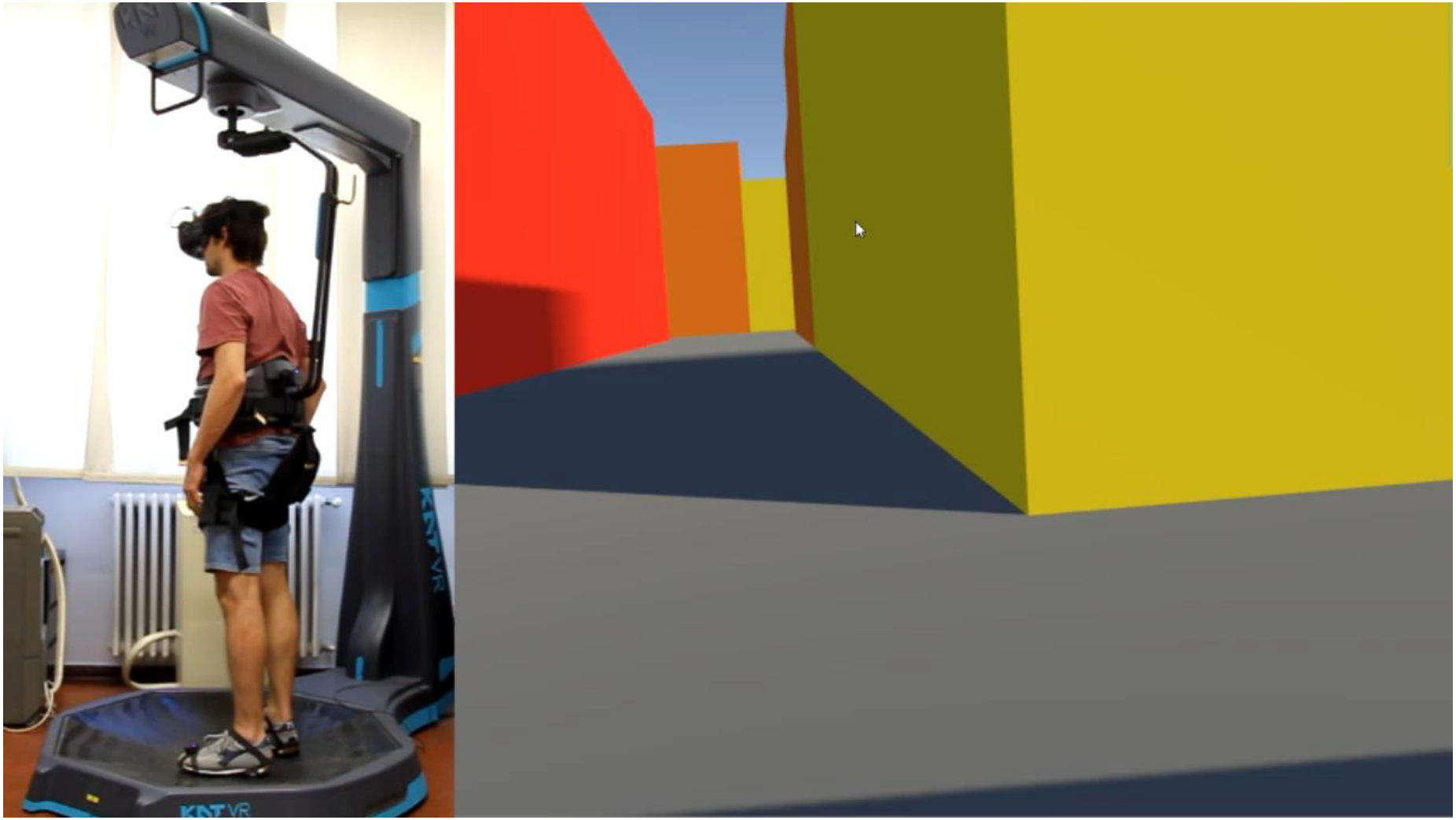
$$\varepsilon = 1.228 + 0.07869 \cdot \left(\frac{a}{b}\right) + 0.05626 \cdot \left(\frac{A_f}{V_b} \cdot \frac{h_b^2}{a}\right)$$

a,b foot print dimensions
Af is the footprint area
hb is the total height
Vb is the total masonry volume



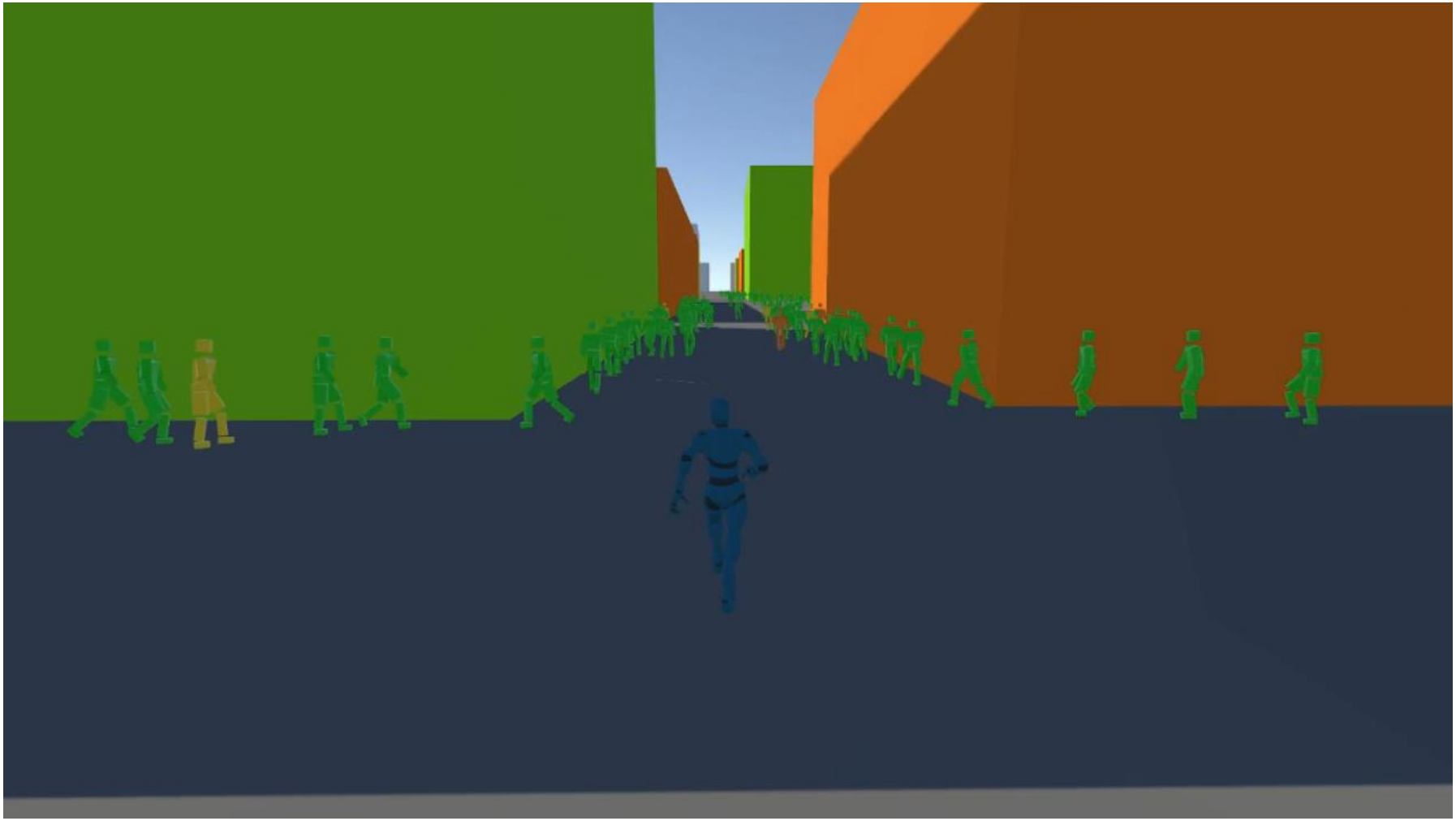
(Domaneschi et al, Eng. Structures 2019, 186, 306-320)

ABM model of evacuation & VR



ABM model of evacuation

(3rd person, injuried individuals)



HUMAN BEHAVIOR
to NOT underestimate evacuation time

Belief-Desire-Intentions (BDI) paradigm implemented through DTF (decision field theory – Lee et al. 2008)

Individual model:

$$P(t+h) = SP(t) + CM(t+h) \cdot W(t+h)$$

Where :

- **P** is the Probability Vector of **Preferences**;
- **S** is the **Stability Matrix: (the memory effect** of previous preference) - Lee's studies: 90% of agent's desires is given by his memory.
- **M** is the **Value Matrix**: **perceptions** of the individual
- **W** is the **Weight Vector**: changes over time according to a stationary **stochastic process**

HB calibration

BDI is calibrated through a survey, powered by GoogleForms®

Emergency Scenario Survey

Informed Content
You are being invited to take part in a research study. The information in this form is provided to help you decide whether or not you want to take part.

What is the purpose of this research study?
The objective of this project is to use an emergency scenario survey to analyze how people evaluate emergencies situations, to develop an accurate simulation model of an emergency evacuation, such as from a explosion, taking into account human behavior.

Will the information that is obtained from me be kept confidential?
No personal information of yours will be collected. The only persons who will know that you participated in this study will be the research team members; specifically, the Principal Investigators and the advisor. Your responses will be confidential. You will not be identified in any reports or publications resulting from the study.

May I change my mind about participating?
Your participation in this study is voluntary. You may decide to not begin or to stop the study at any time. Also any new information discovered about the research will be provided to you.

Whom can I contact for additional information?
You can obtain further information about the research or to voice concerns or complaints about the research by calling the Principal Investigators.

Noticed : to fill out the questionnaire you must be connected to Internet

Gender	Age	Education
○ male	○ 15-30	○ elementary school
○ female	○ 31-45	○ middle school
	○ 46-60	○ high school
	○ 61-80	○ bachelor degree
		○ master degree or higher

We ask you to watch a video clicking on the link below before filling the survey

VIDEO

As shown in Figure 1 below, you are in a museum and you are heading in the direction of the green arrow.
If a explosion occurs and this blast has caused death, injured and people with eardrum rupture (this means temporary hearing loss and disorientation).
After the blast you must evacuate to a safe area. Your options are to find an emergency exit yourself or to join a group of people who are also running away.

Assuming that
- You are not injured and without eardrum rupture
- You are alone without any relative or friend
- You do not see any emergency exit

Figure 1. Depicts of a museum room

Question 1

	Very unlikely	Unlikely	Neutral	Likely	Very Likely
How likely is that you would decide to evacuate on your own?	○	○	○	○	○

Question 2

	Definitely	Probably	Not sure	Probably not	Definitely not
Would you decide to join a group of people who are running away from the blast?	○	○	○	○	○

Conclusion

- The VR platform can allow individuals **to experience realistic FFE scenario** → to improve evacuation procedures and SAR
- It can help designer and decision makers to **improve existing structures and release updated standards**
- It can **provide information on the human behaviors** under emergency conditions

Thank you for your attention

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