Tsunami Evacuation Experience System Based on Multi-Agent Model using Smart Device

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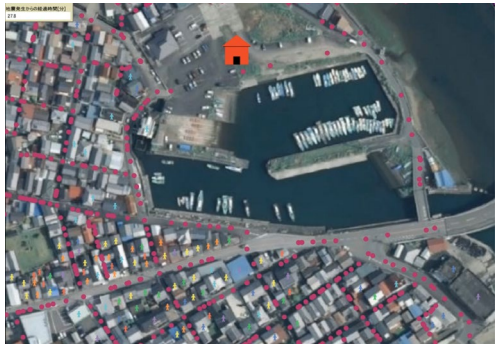

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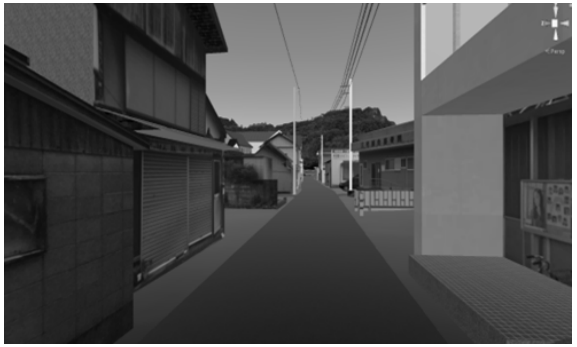
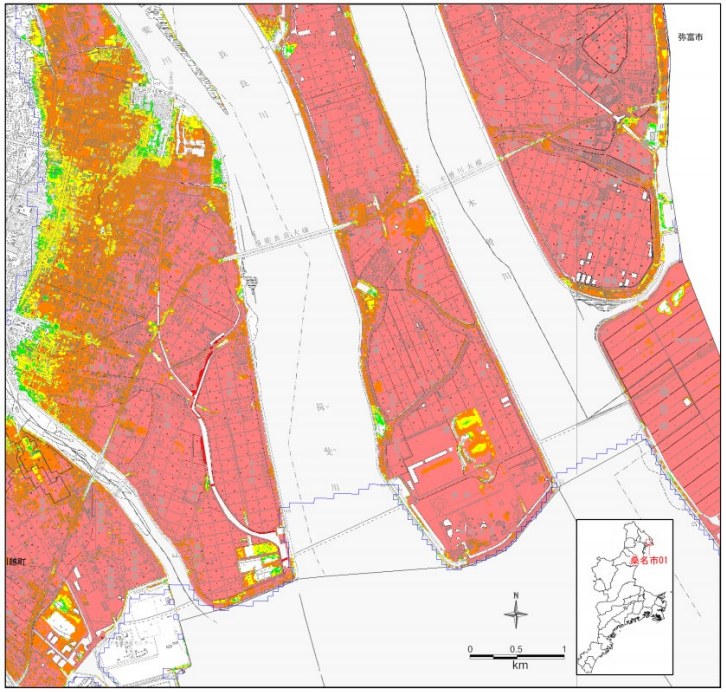


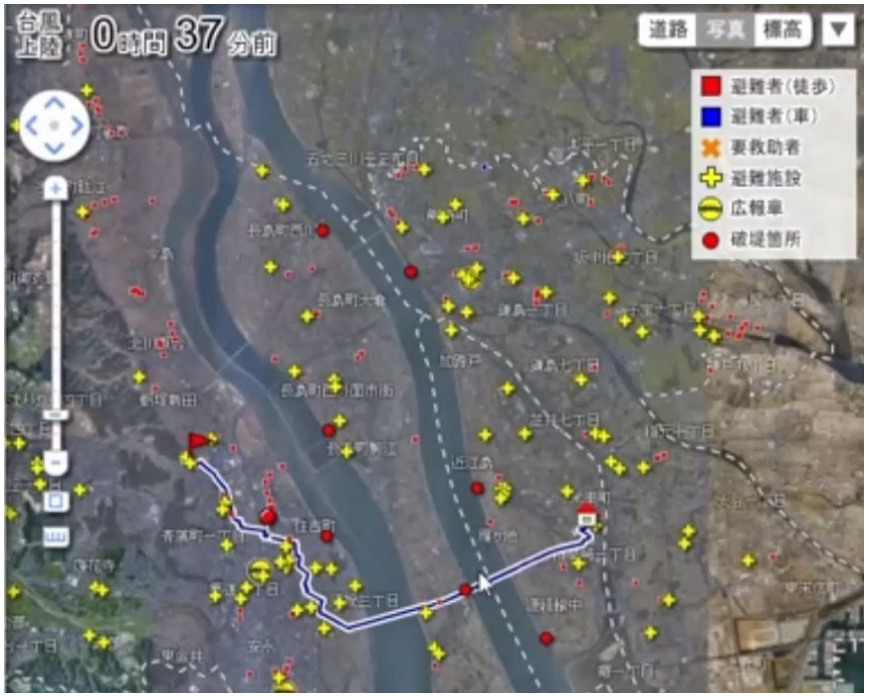
1. INTRODUCTION

Hazard map has been made to raise disaster prevention awareness,
But …**Cannot image Tsunami damage too much.**

Tsunami hazard map



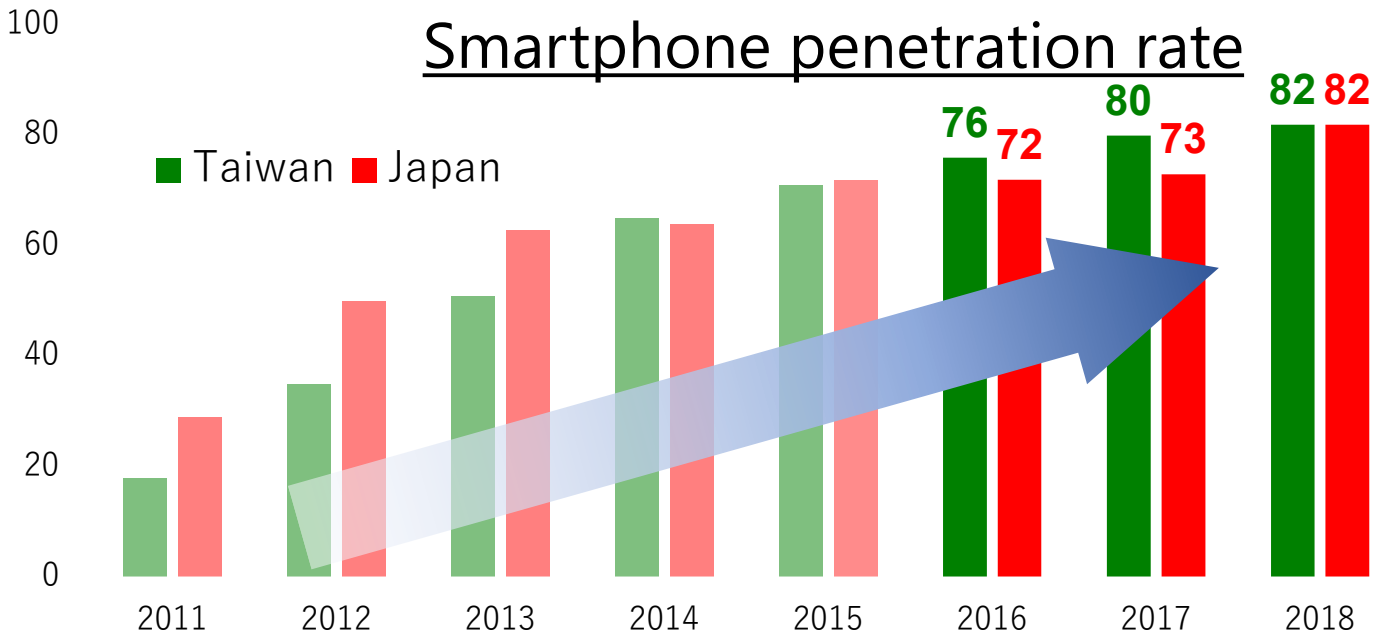
Static



Dynamic

1. INTRODUCTION

Smartphone can be cited as familiar VR devices and their penetration rate goes up year by year.



80% or more

source:i-FIND reports
「臺灣消費者行動裝置
APP使用行為研究調查報告」

Developed a useful system for the education for disaster mitigation by VR using smart device.

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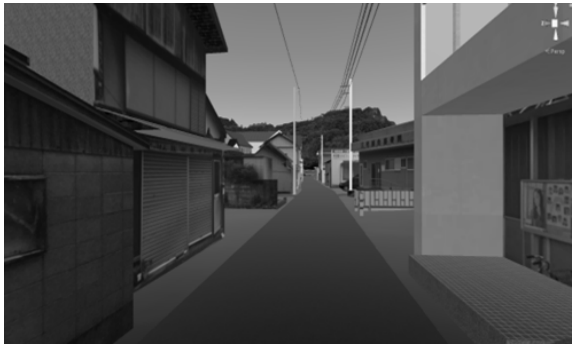


2. SUMMARY OF SYSTEM

Digital city model

Tsunami Simulation

Evacuation Simulation

Integrate

unity

Using Unity※ ,integrate results and models into VR

※Unity is a cross-platform 3D content creation engine

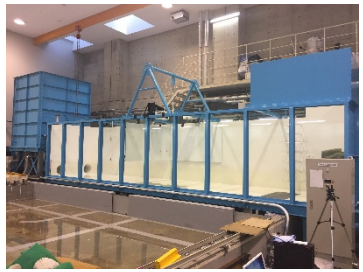
Output

Smartphone

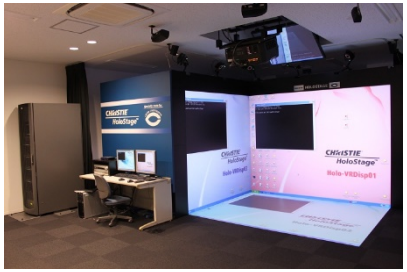
Smartphone as HMDs

PC-Powered HMDs

water tank as Evacuation Training Equipment



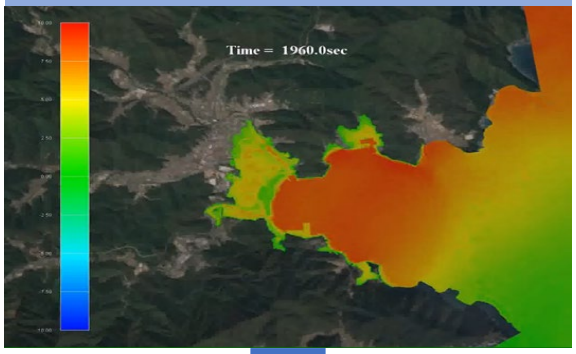
immersive VR environment HoloStage



2. SUMMARY OF SYSTEM

Digital city model

Tsunami Simulation



Evacuation Simulation

Integrate Digital city model and Tsunami simulation result into VR

Create 3D walking Fig.

Integrate evacuation simulation result into VR

Create scripts

Output to VR devices

RPT. Output to smart device (smartphone and as HMDs)

Smartphone

Smartphone as HMDs

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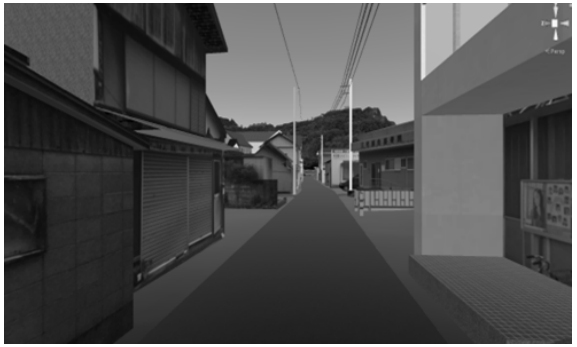


3. INTEGRATIONS OF MODEL ①DIGITAL CITY MODEL TO DISPLAY

- **Low Resolution（Large area）**

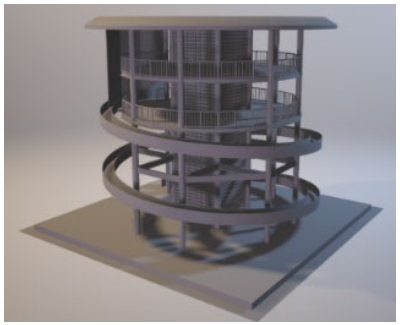
  Paste Satellite images to terrain model using publicly available data

- **Medium Resolution（Medium area）**

  Reconstruct 3D shape by SfM/MVS taken with UAV

- **High Resolution（narrow area）**

  Convert from 2D image (ex.photo/drawing) to 3D shape using CAD



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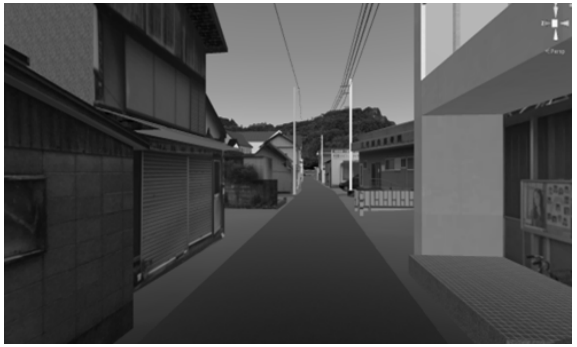


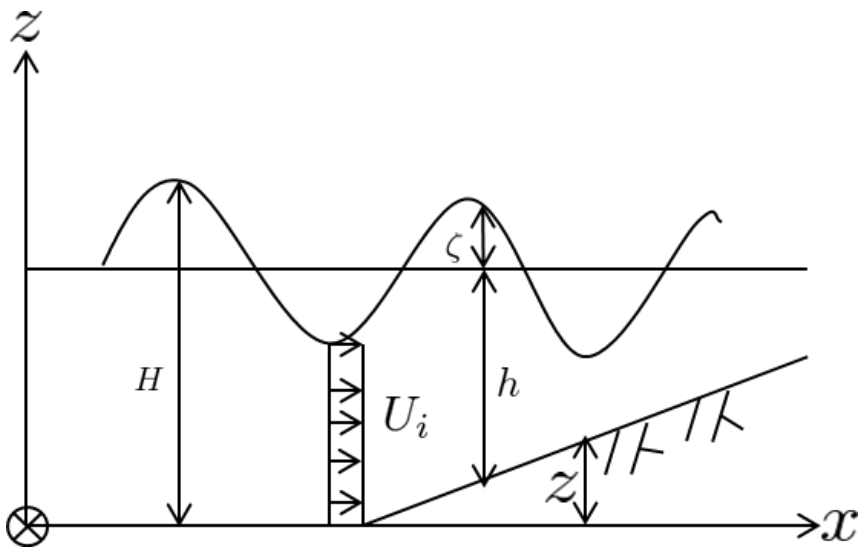
Governing Equations

- Shallow Water Equation

$$\frac{\partial(U_i H)}{\partial t} + \frac{\partial(U_j U_i H)}{\partial x_j} + \nu_e \frac{\partial^2(U_i H)}{\partial x_j^2} + \frac{g n^2 U_i \sqrt{U_j U_j}}{H^{\frac{1}{3}}} + gH\frac{\partial(H+z)}{\partial x_i} = 0$$

- Continuity Equation

$$\frac{\partial H}{\partial t} + \frac{\partial(U_i H)}{\partial x_i} = 0$$

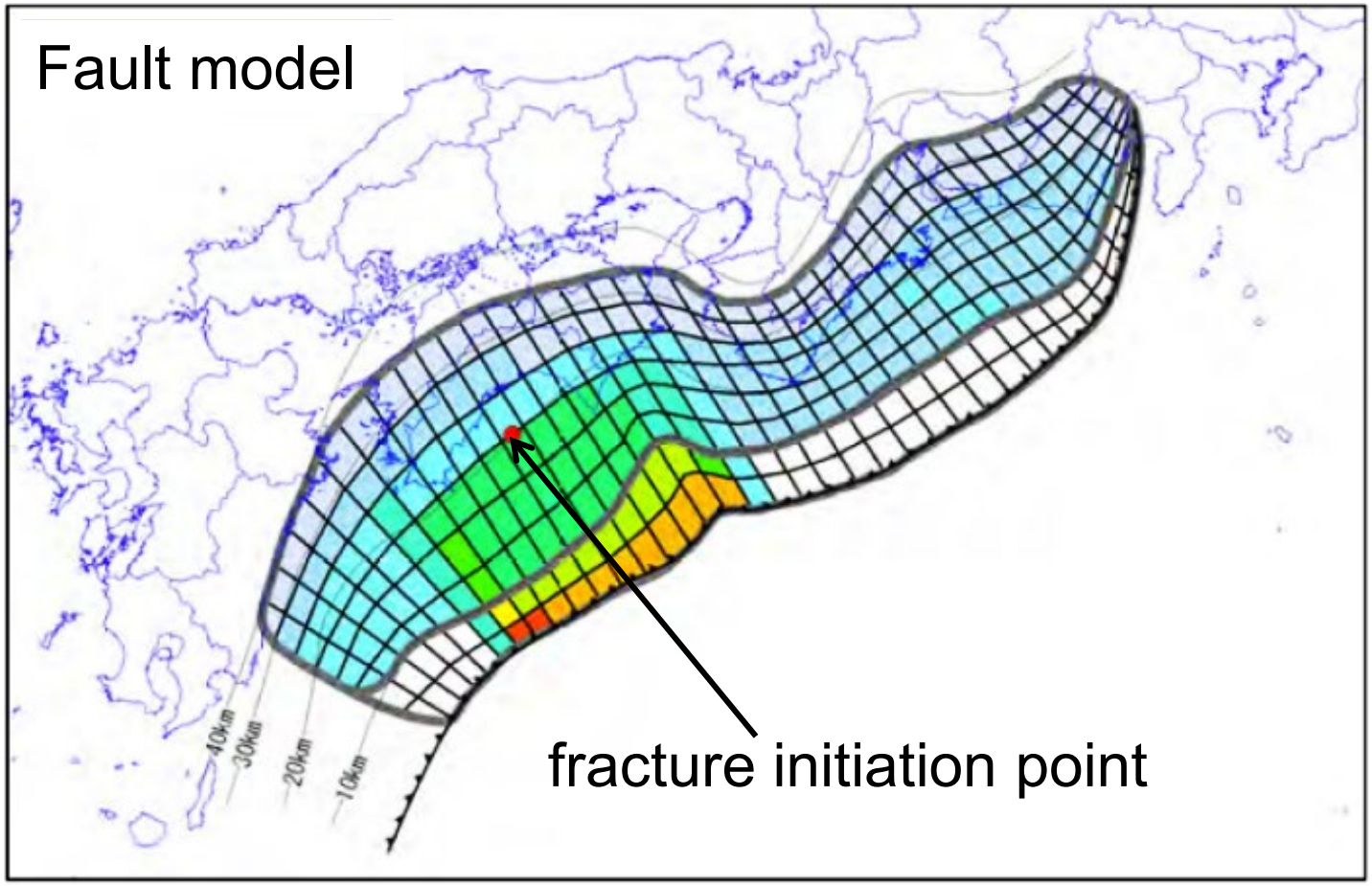


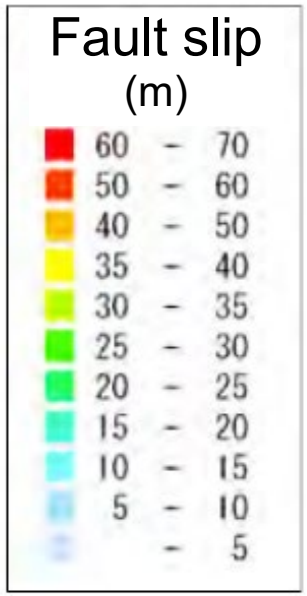
H : Total water depth
h : Static water depth
g : Acceleration of gravity
z : The height of ground

U_i : Mean velocity (U_1, U_2)
ν_e : Eddy viscosity coefficient
n : Manning's Roughness Coefficient
ζ : Wave elevation

3. INTEGRATIONS OF MODEL ②RESULT OF TSUNAMI SIMULATION

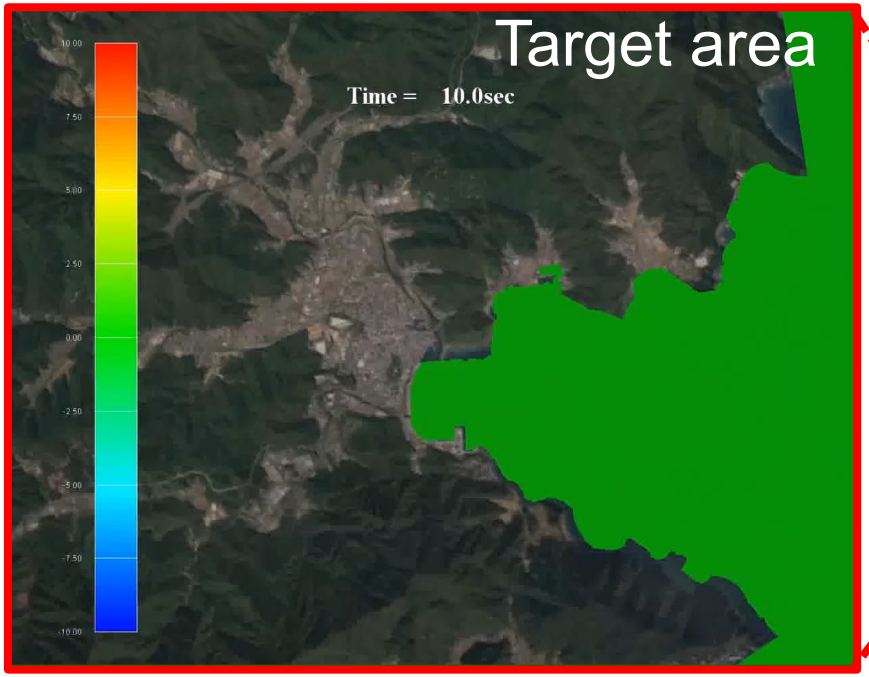
- Initial condition for Tsunami

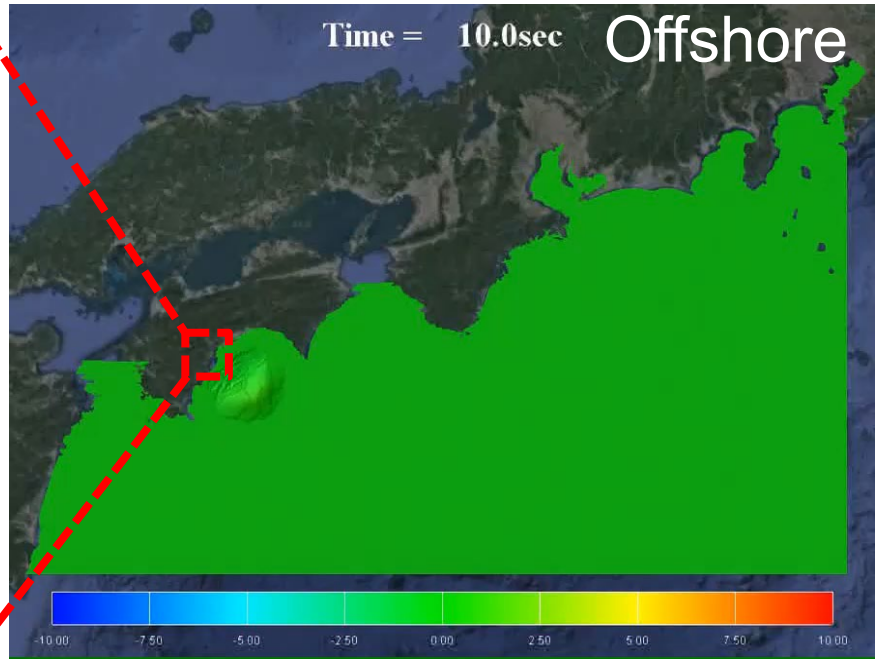




3. INTEGRATIONS OF MODEL ②RESULT OF TSUNAMI SIMULATION

Tsunami simulation Result





Target Area :
Kure, Nakatosa-town,
Kochi Prefecture, Japan

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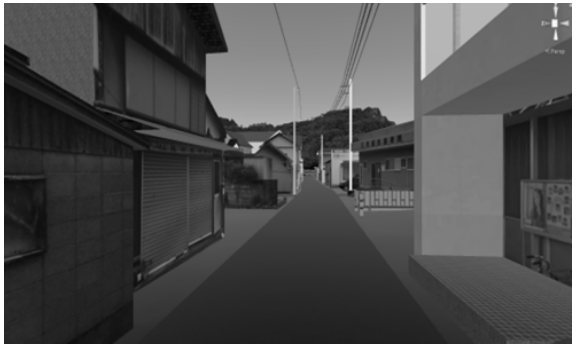


3. INTEGRATIONS OF MODEL ③RESULT OF EVACUATION SIMULATION

Target

Area：Kure, Nakatosa-town,
Kochi Prefecture, Japan
Refugee : 3,526 (household),
Evacuation site : 26

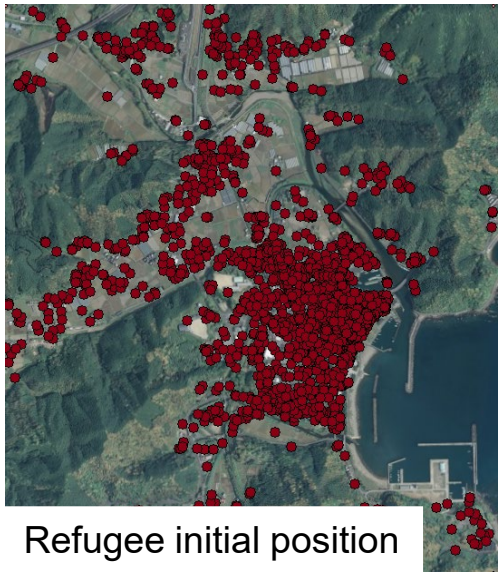
Method

Multi-agent Simulation (MAS) Considering…

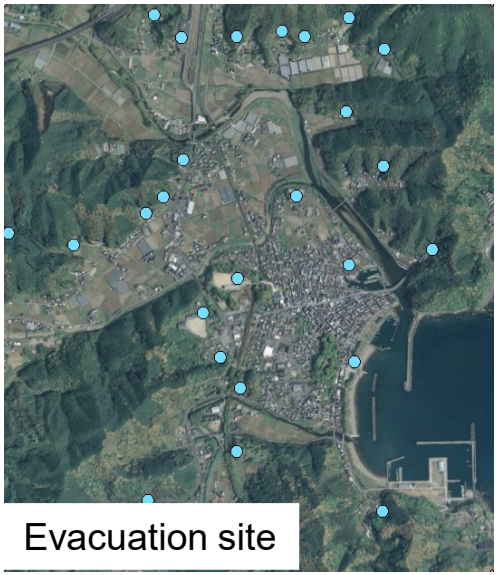
- **Route selection**
  distance / elevation / water's edge / majority synching bias/ avoiding flooded path
- **Walking speed**
  by age / gradient / crowding / fatigue
- **Determine by damage**
- **Shelter capacity**

3. INTEGRATIONS OF MODEL ③INPUT DATA

- Input data for evacuation analysis

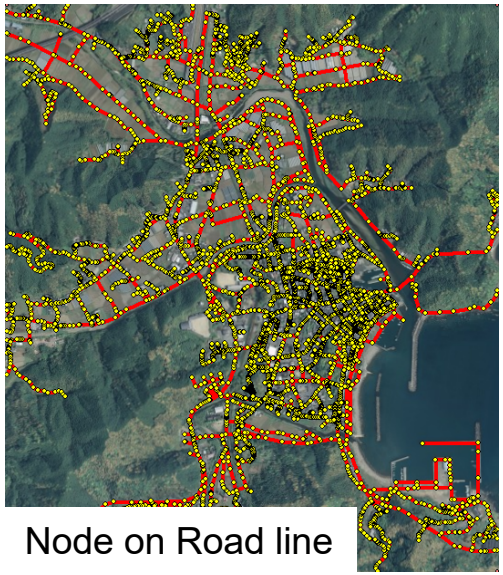


Refugee initial position

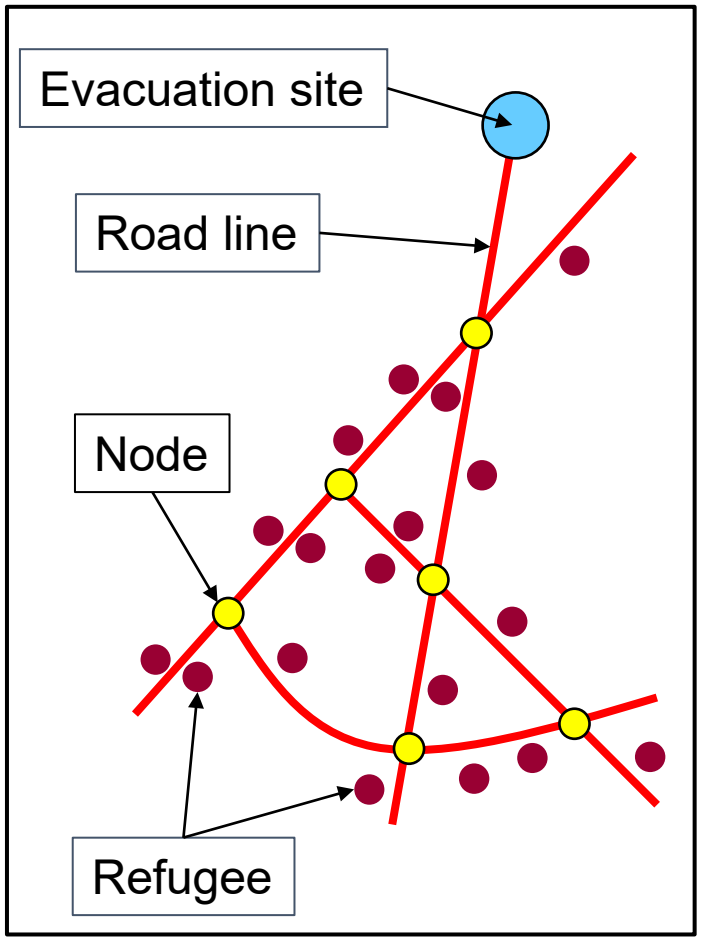


Evacuation site

Road line



Node on Road line



Input data from public data

3. INTEGRATIONS OF MODEL ③ROUTE SELECTION

Judgement of refugee's route

$$S_{\text{Utility}} = \frac{a}{s^{\alpha}} - \frac{b}{z^{\beta}} - \frac{c}{w^{\gamma}} - \frac{d}{t^{\delta}}$$

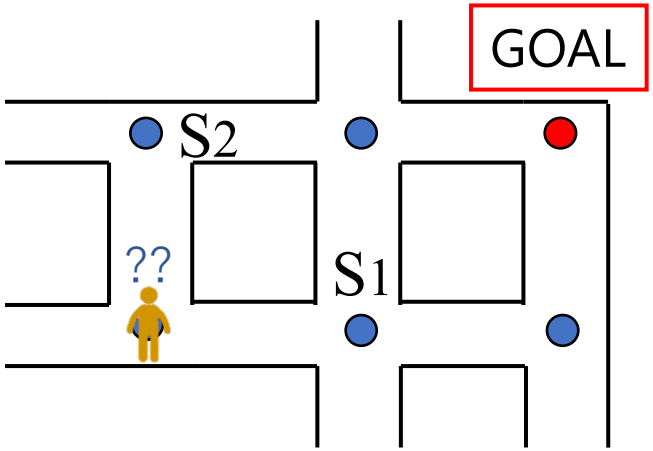
Distance from evacuation

elevation

Distance from Water's front

majority synching bias

S: Utility (Judge larger S)
a, b, c, d : weighting coefficient
$\alpha, \beta, \gamma, \delta$: weighting coefficient of distance
s : distance from evacuation site
z : elevation
w:distance from water's front
t : number of people



Each node has Each **S**

If S1 > S2, Refugee Move to S1

3. INTEGRATIONS OF MODEL ③WALKING SPEED

Speed by Age

S.Kagaya, et al. (2011)

AGE	-14	15-34	35-54	55-64	65-74	75-84	85-
M	1.33	1.47	1.39	1.41	1.32	1.04	0.50
F	1.29	1.44	1.36	1.46	1.48	1.32	0.62

(m/s)

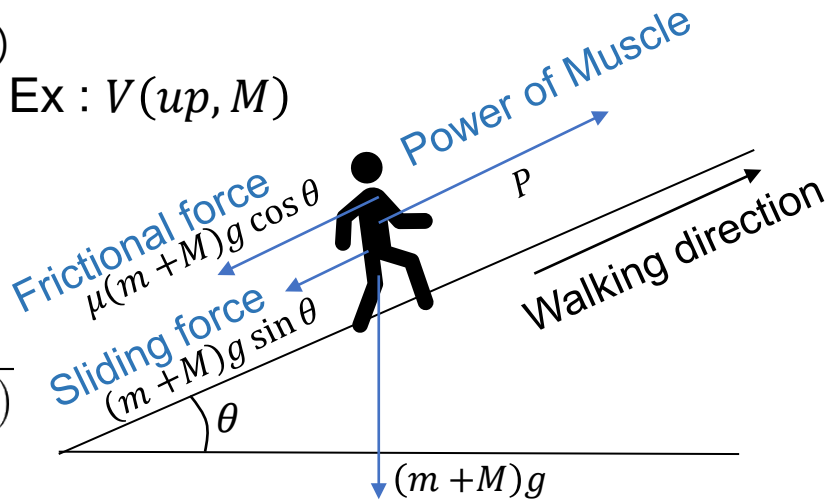
Speed by Gradient

A.Morimoto, et al. (2004)

$$V(up, M) = \frac{P}{(m+M)g(\mu \times cos\theta + sin\theta)}$$

$$V(down, M) = \frac{P}{(m+M)g(\mu \times cos\theta - sin\theta)}$$

Ex : $V(up, M)$



P : Power of Muscle, m : Body weight, M : Load,
g : Gravity acceleration, μ: coefficient of friction, θ: Gradient

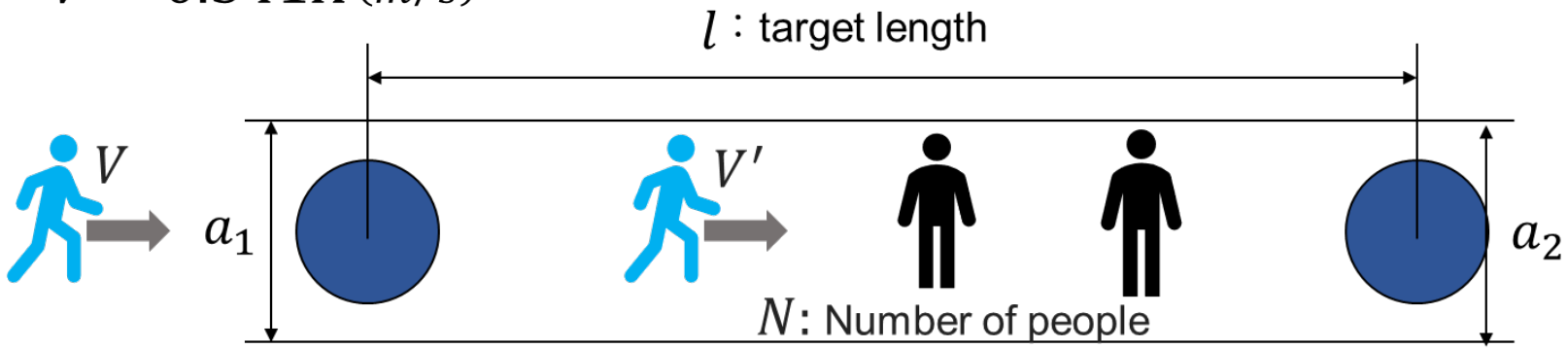
3. INTEGRATIONS OF MODEL ③WALKING SPEED

Speed by Crowding J.Fruin, et al. (1974)

$$K = \frac{N}{\{(a_1 + a_2) \times l \div 2\}} \text{ (Number of people / m)}$$

$$V' = V - 0.341K(m/s)$$

K:Density, a_1, a_2: Road width
N: Number of people
V: Walking speed
V': New walking speed

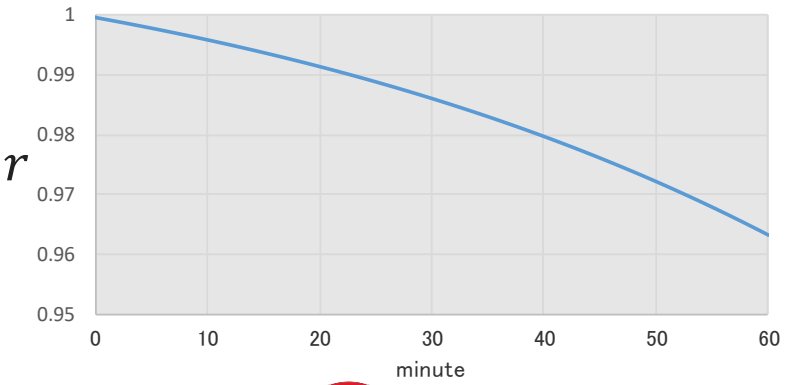


Speed ratio by Fatigue T.Katada, et al. (2013)

$$r = \frac{1}{\{0.982 + exp(1.12t - 4)\}}$$

r : Coefficient of fatigue speed , t : Passed time (hour)

Fatigue speed drop by time change



3. INTEGRATIONS OF MODEL ③DETERMINE BY DAMAGE

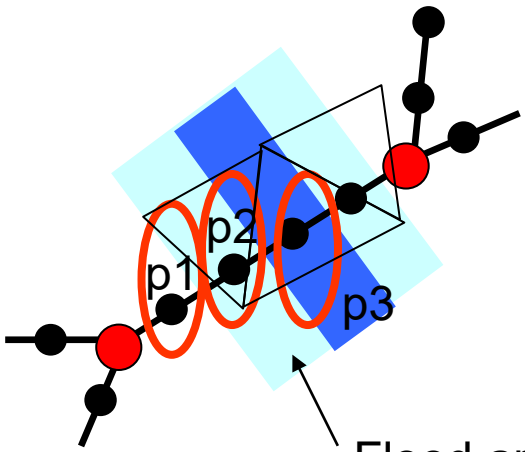
Relationship between flow velocity, water depth and refugee's status

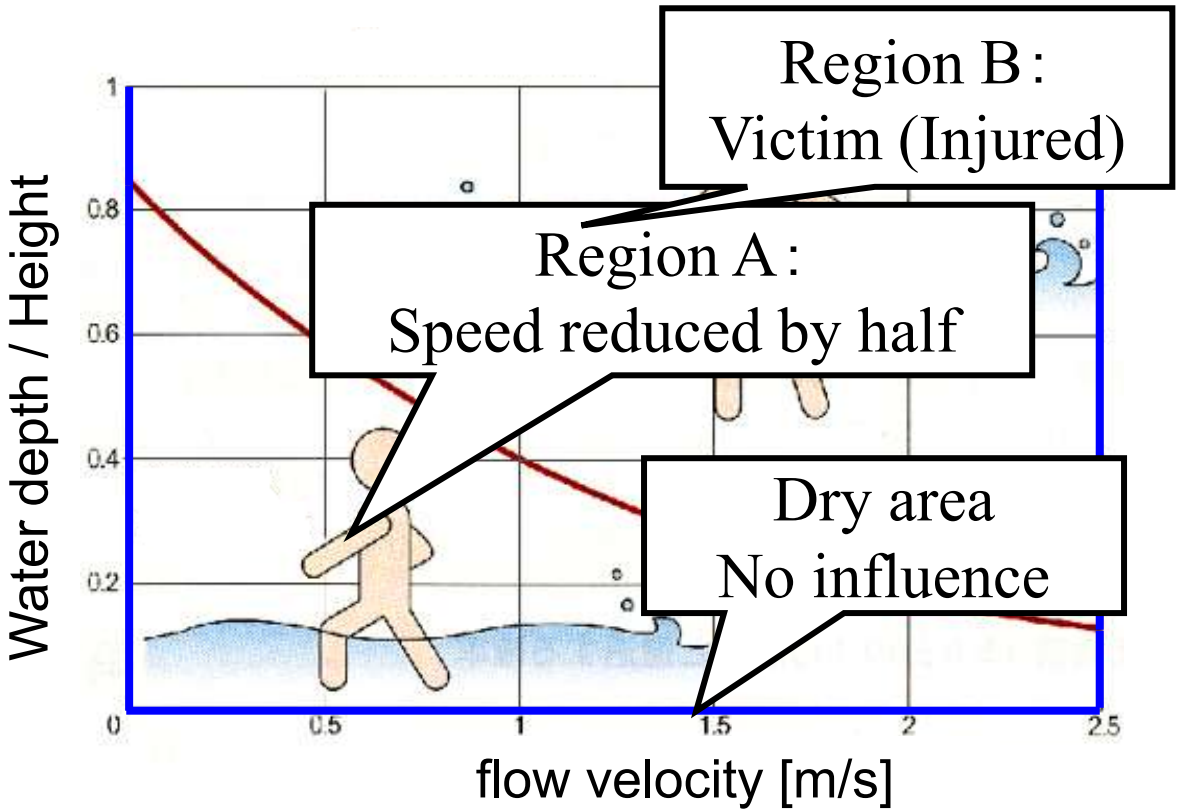
Flood(region A)

Flood(region B)

Observation point of flood

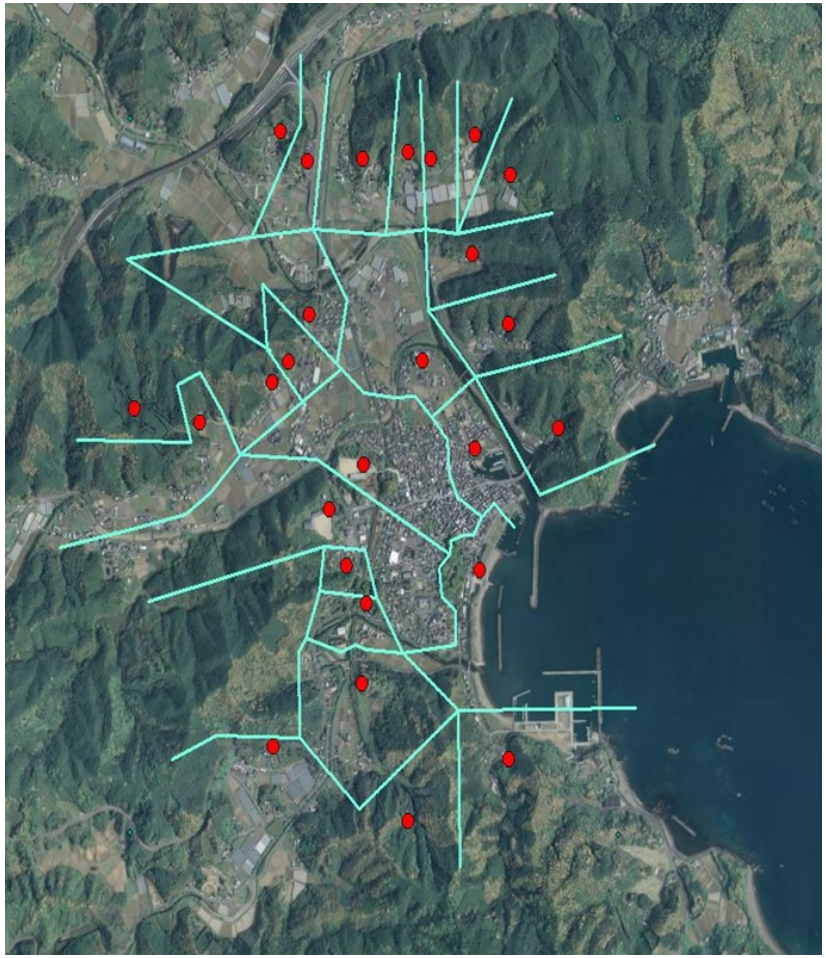
Intersection

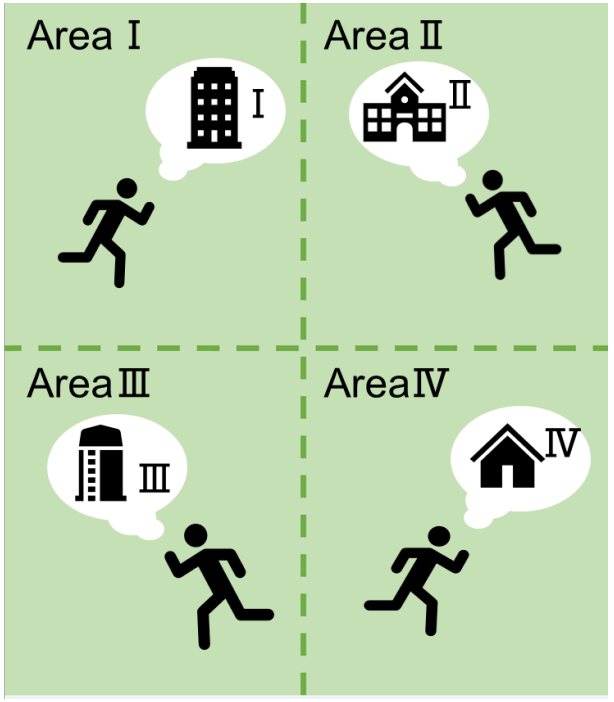




Suga, et al. (2000)

3. INTEGRATIONS OF MODEL ③SHELTER CAPACITY



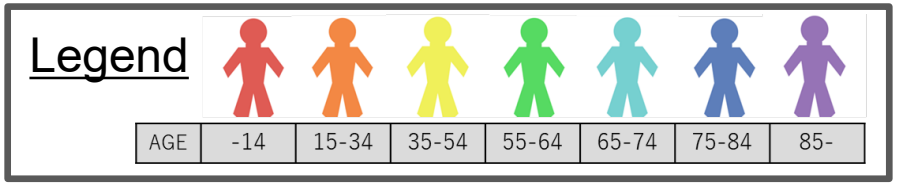


Set up initial shelter as not to exceed the capacity of the shelter using Voronoi division.

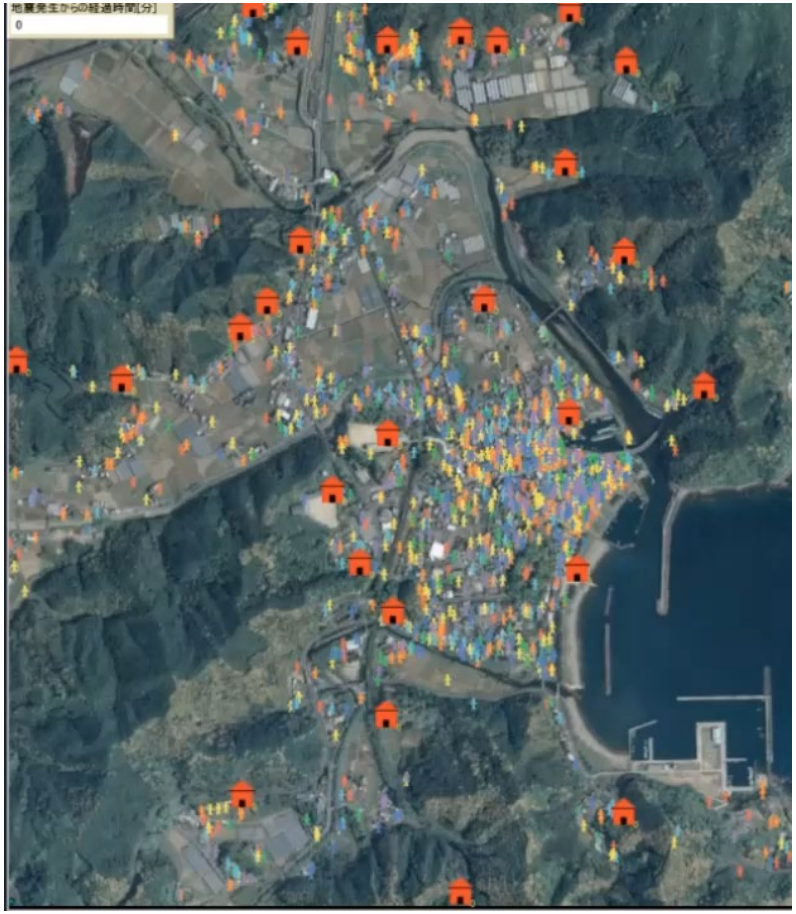
3. INTEGRATIONS OF MODEL ③RESULT OF EVACUATION SIMULATION

- Evacuation Result

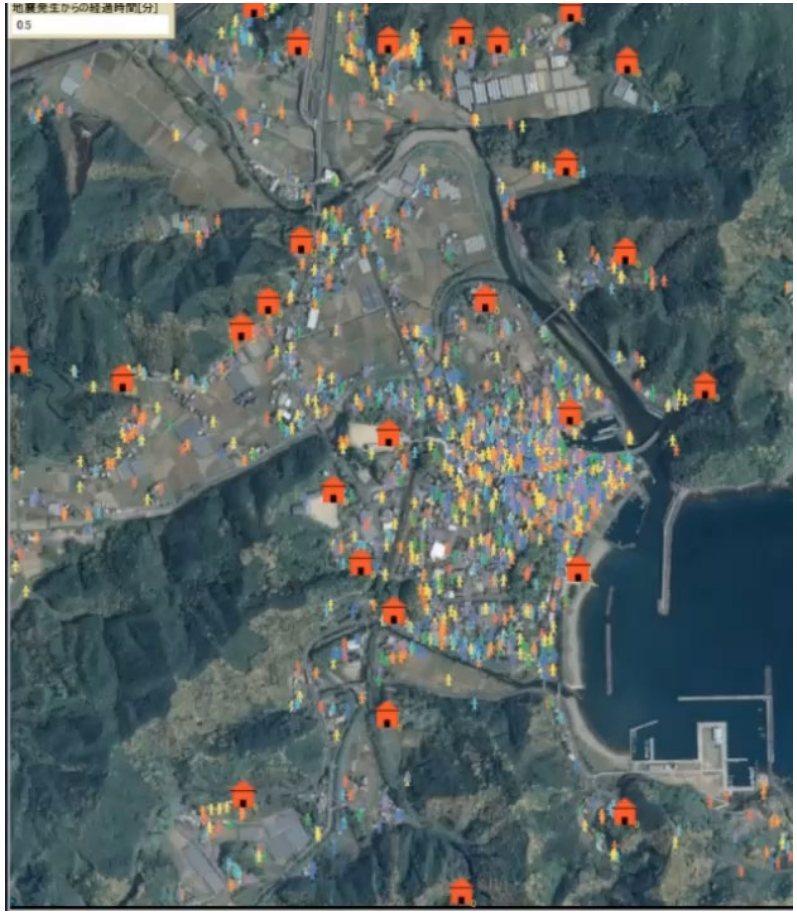
Evacuation starts…



10 min after Earthquake



30 min after Earthquake



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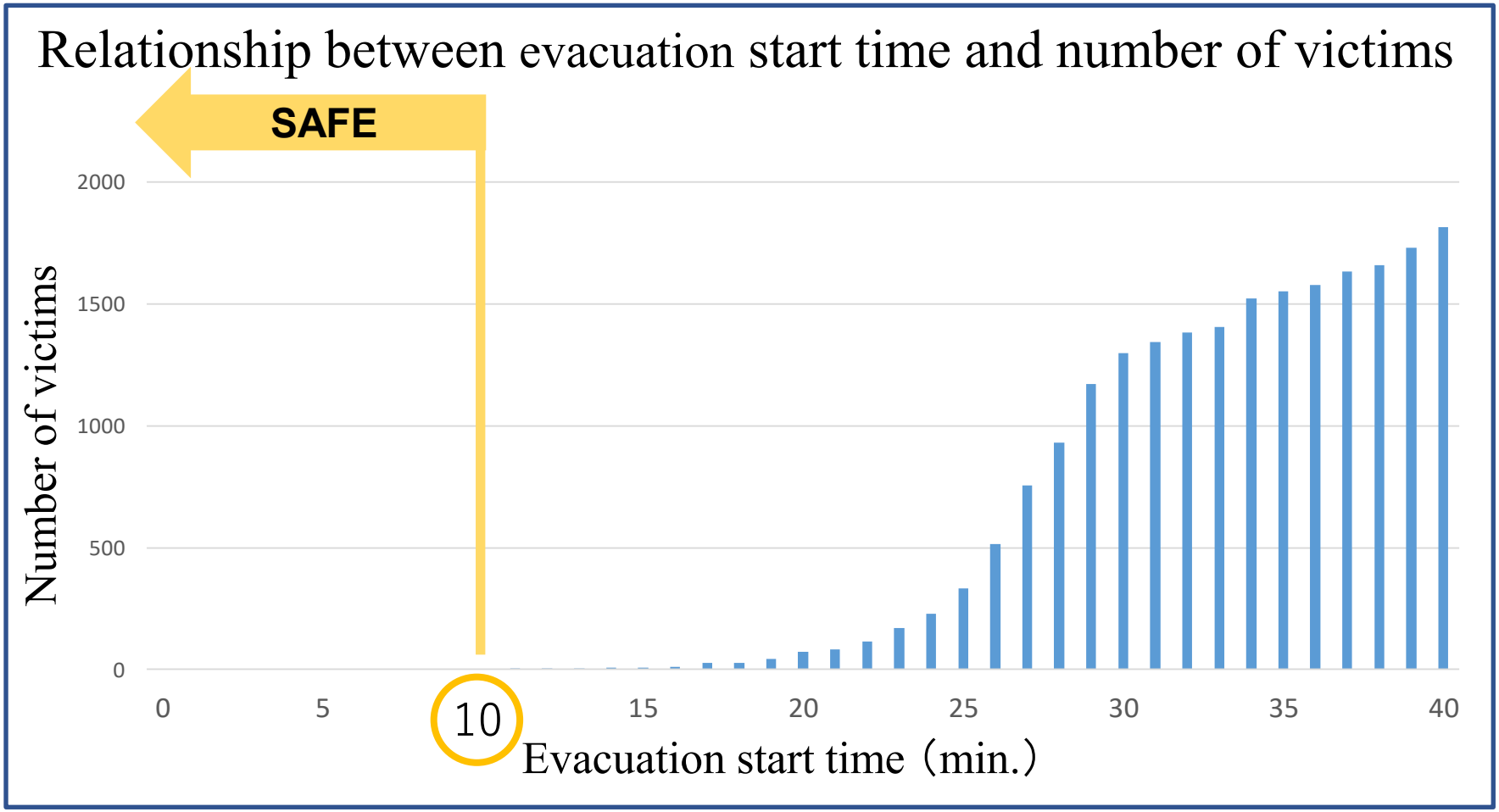

It is safe if you start evacuation
within 10 minutes after the earthquake.

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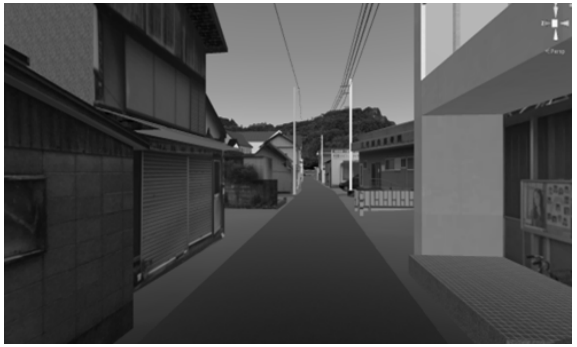
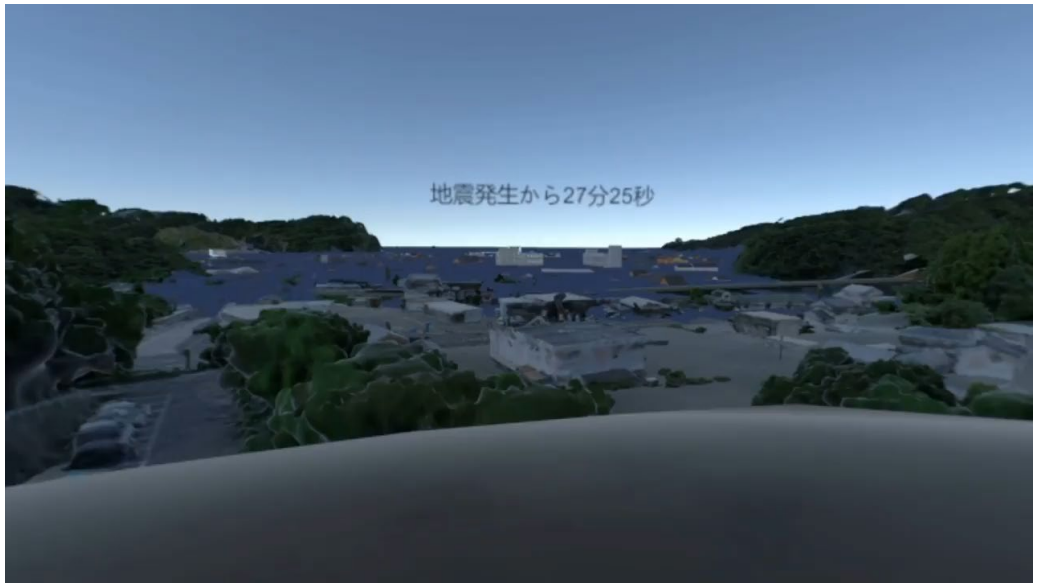


3. INTEGRATIONS OF MODEL ④OUTPUT TO ANY DEVICE

- Animation of refugee's viewpoint

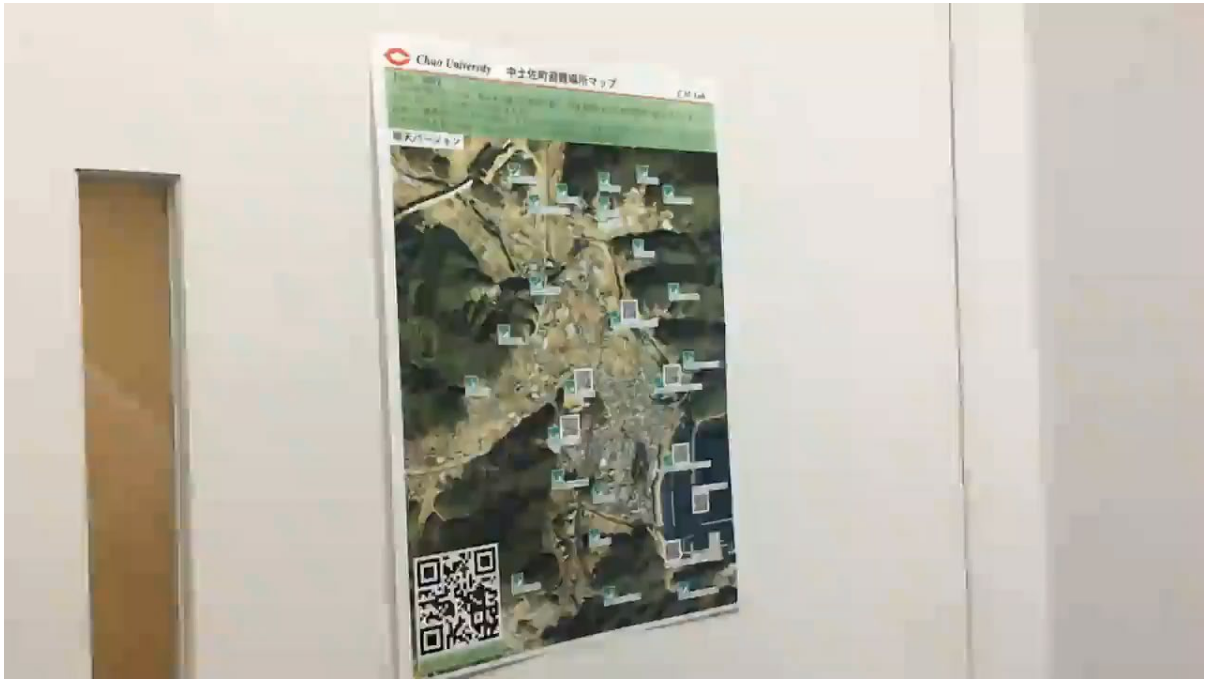


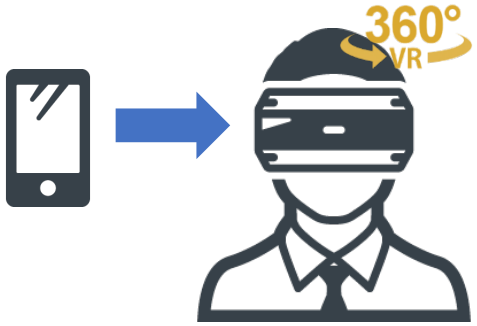
View from Evacuation Site

View from Evacuating
(Swallowed up by Tsunami)

3. INTEGRATIONS OF MODEL ④OUTPUT TO ANY DEVICE

How to use of the present system





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4. CONCLUSION

Developed a useful system for the education for disaster mitigation by VR using smart device.

- Developed a highly applicable evacuation simulation method using multi-agent model
- Integrated the digital city model, Tsunami / Evacuation simulation result on Unity
- Developed a system to experience using smart devices

Future work

- Improve the applicability of evacuation simulation
- Enhance the reality of VR

THANK YOU FOR YOUR KIND ATTENTION.