

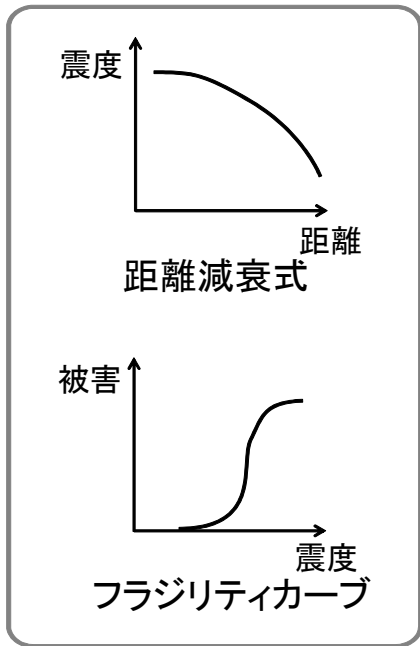
京計算機を使う構造物と都市の 大規模地震応答シミュレーション

堀宗朗

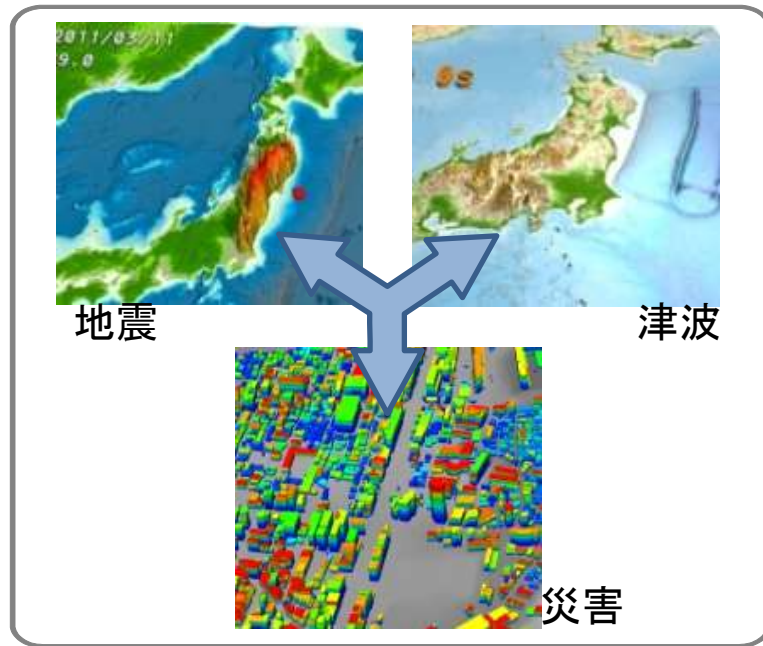
東京大学地震研究所

巨大地震津波による災害予測の現状と将来

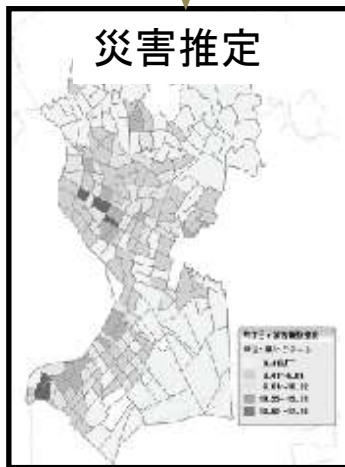
現状 経験ベース



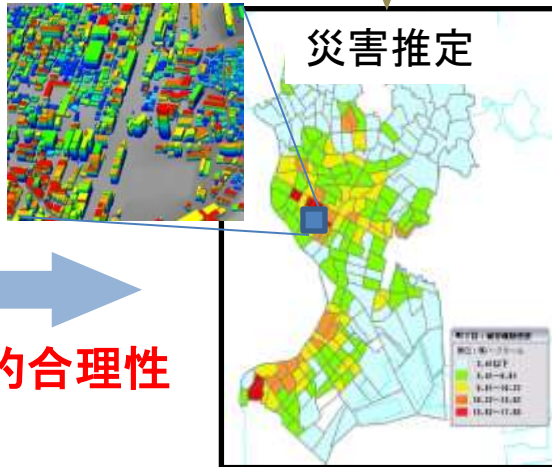
将来 計算ベース



都市を1km程度四方の領域に分け、過去のデータの統計解析を基に、各領域での地震動と被害を計算する。経験ベースであるため信頼度は決して高くない。他に代替がなかったため、経験ベースの予測に頼らざるを得なかった。



地震・津波の物理過程のシミュレーションと構造物一棟一棟の応答シミュレーションから、災害を予測する。図示された予測は、現状と一見、変わらない。しかし、信頼度は大きく改善されることが期待できる。計算科学の進歩を最大限利用した計算ベースの予測は高い科学的合理性を持つからである。



科学的合理性

防災・減災に資するシミュレーション

- リスクマネジメントの枠組み
 - 想定 地震・津波・災害の予測
 - 判断
 - 対処 ハードウェア 耐震設計, 耐震補強
 ソフトウェア 保険
- シミュレーションの役割
 - 経験ベースからシミュレーションベースへ
 - 保険産業の信頼を得る科学的合理性

構造物のシミュレーション


- 超高層ビル

- High Fidelity モデル 

- 地盤-構造連成の大規模計算 

- RC橋脚

- 破壊モデル  

- 鉄筋コンクリートの破壊現象 

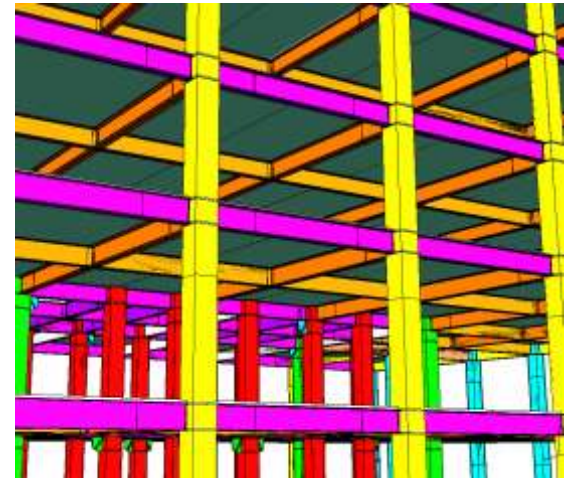
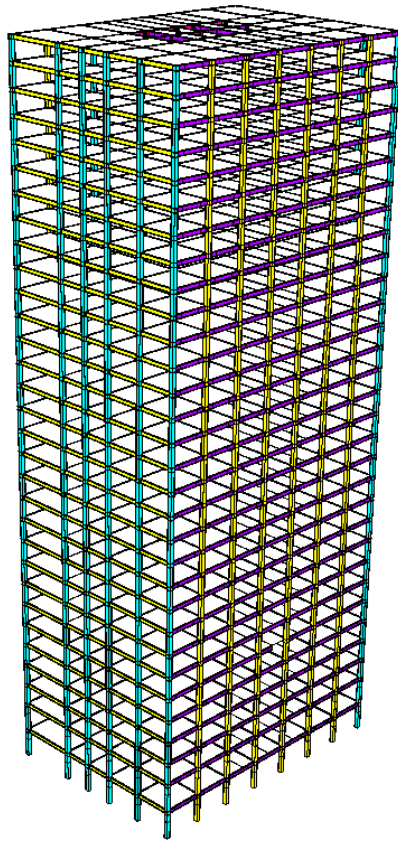
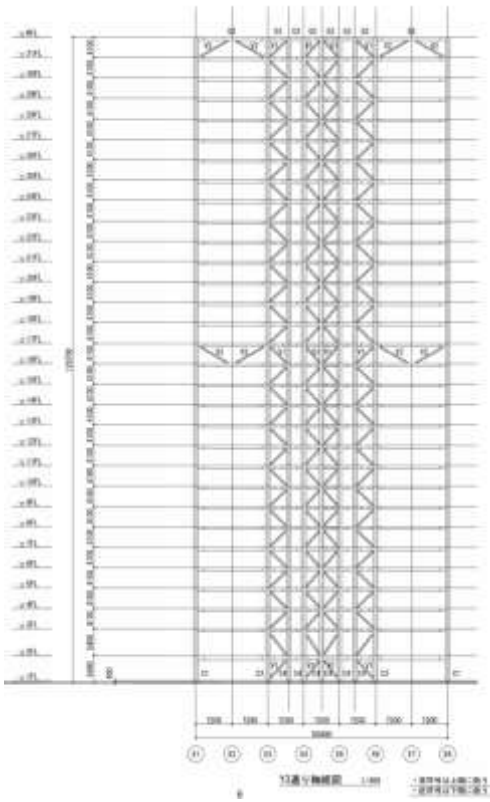
京計算機

- 戦略プログラム3 地震
 - 地震シミュレーション 古村(東大)
 - 津波シミュレーション 今村(東北大)
 - 構造・都市シミュレーション
- 総合防災・減災研究ユニット
 - 集中豪雨
 - 地震・津波, 地盤祭儀

構造物のシミュレーション

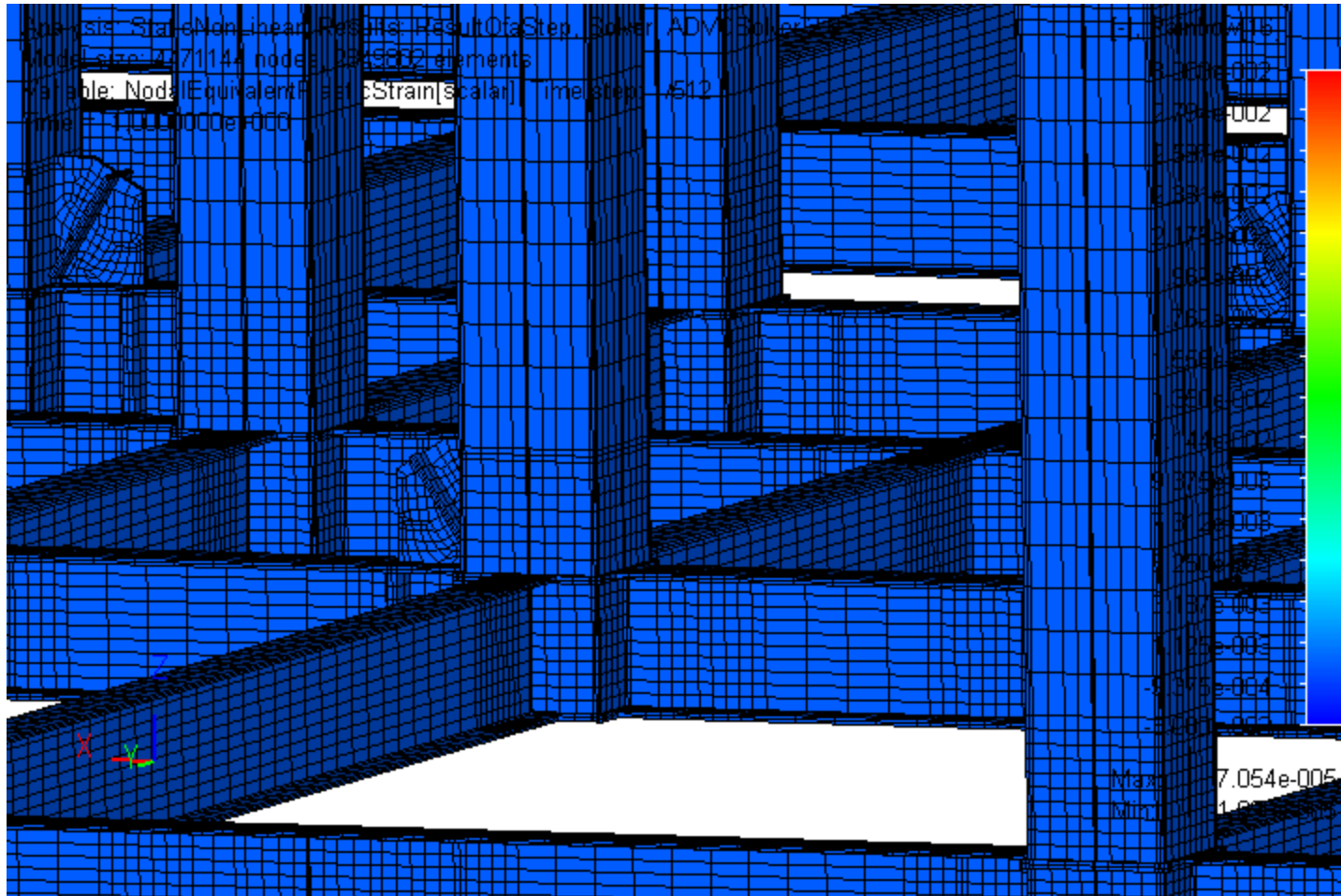
- 超高層ビル
- RC橋脚
- 大型トンネル

HIGH RISE BUILDING



Use of CAD data for high-rise building

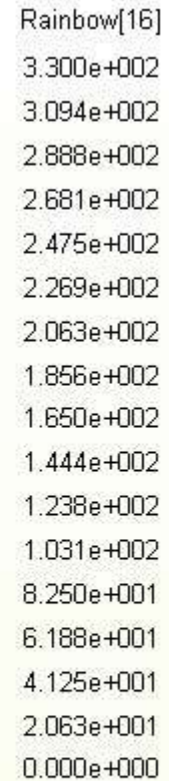
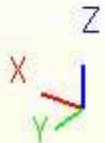
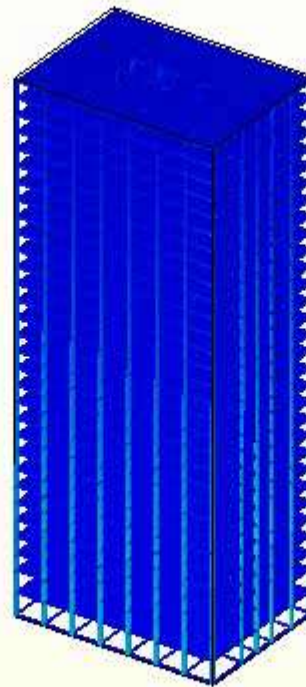
RESULTS



RESULTS

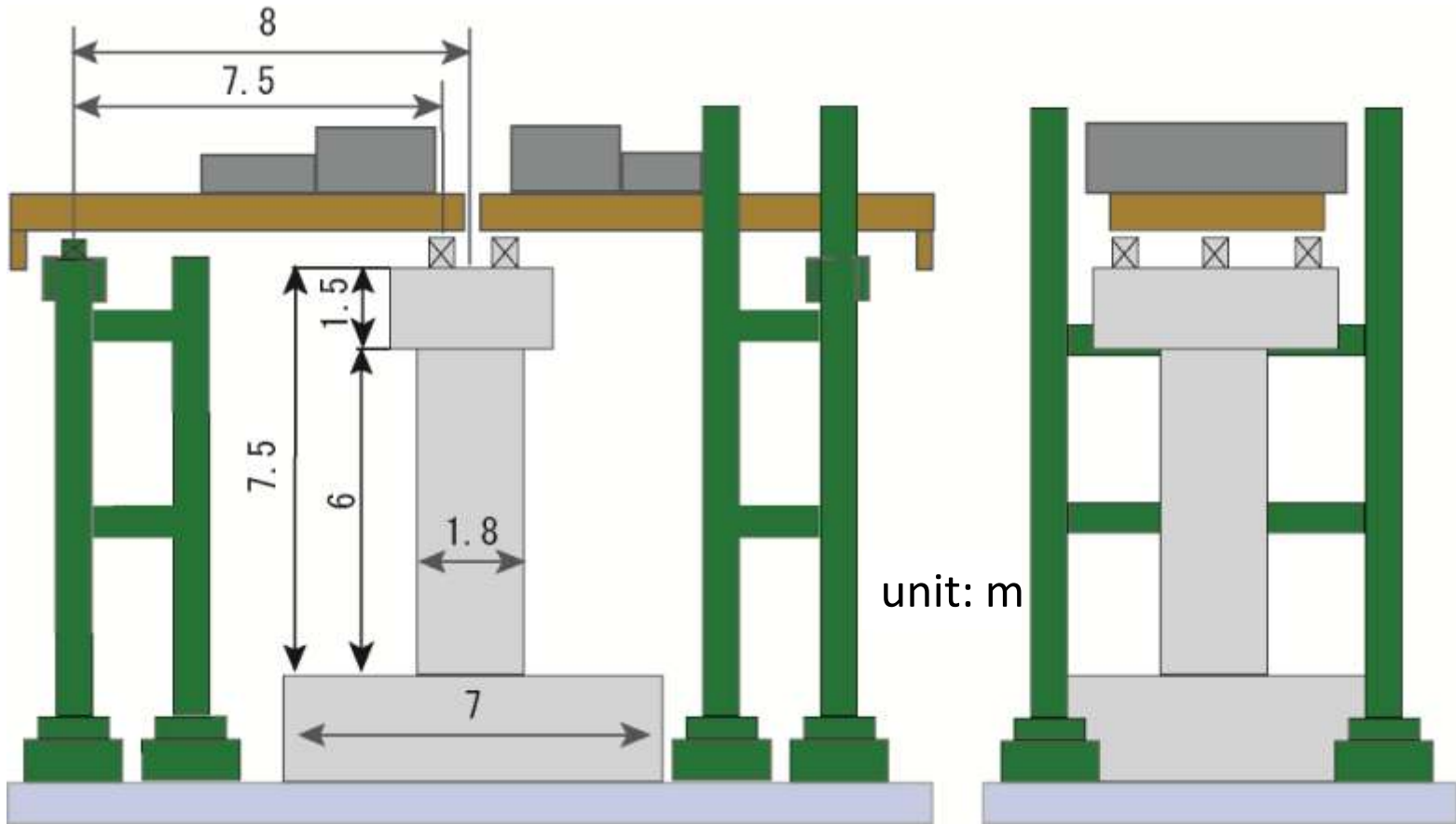


Analysis: StaticNonLinear, Results: ResultOfaStep, Solver: ADVCSolver 2.0
Model size: 24765275 nodes, 15632501 elements
Variable: NodalEquivalentStress[scalar], Time step: 1/50
Time = 1.0000000e+000

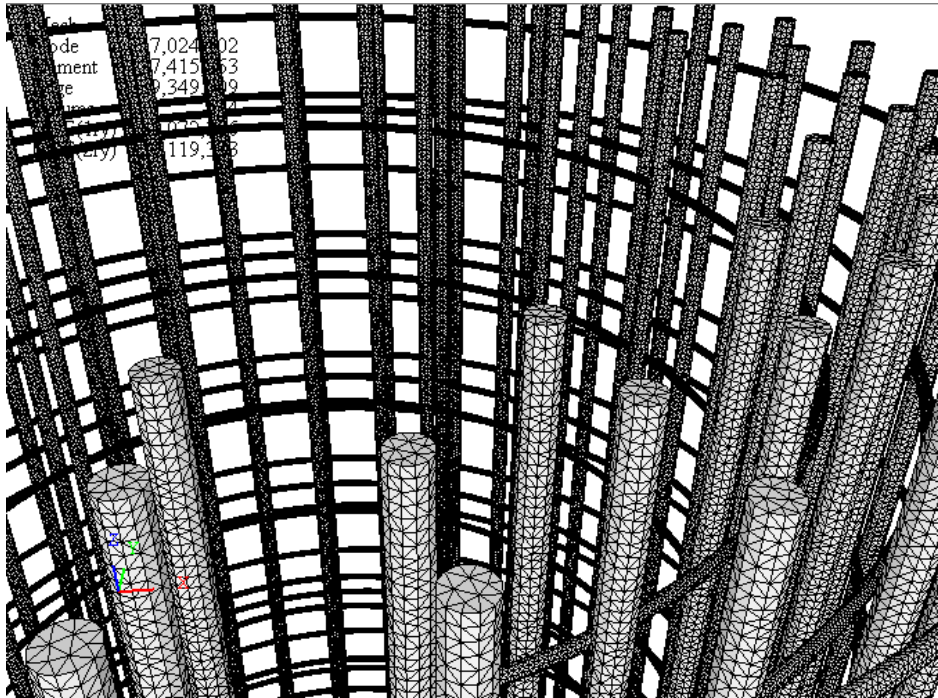


Max: 3.149e+002
Min: 1.346e-002

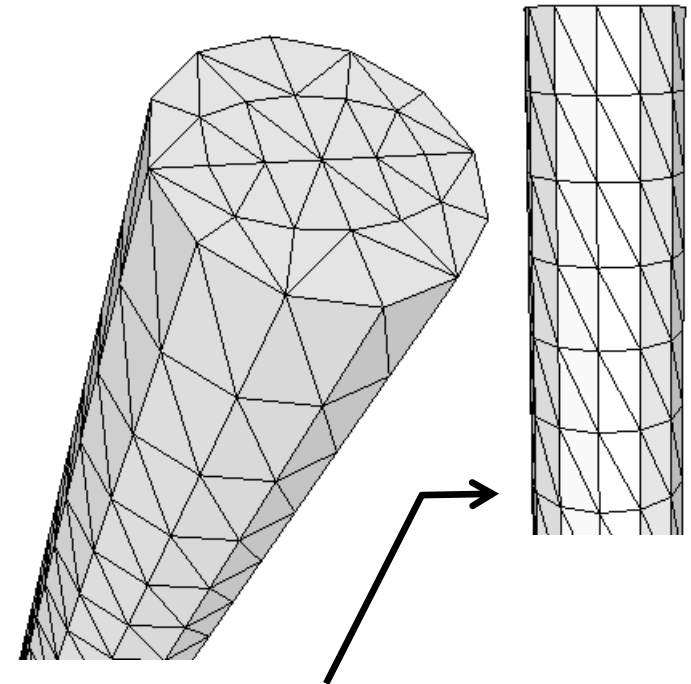
EXPERIMENT



DETAILED MODELING

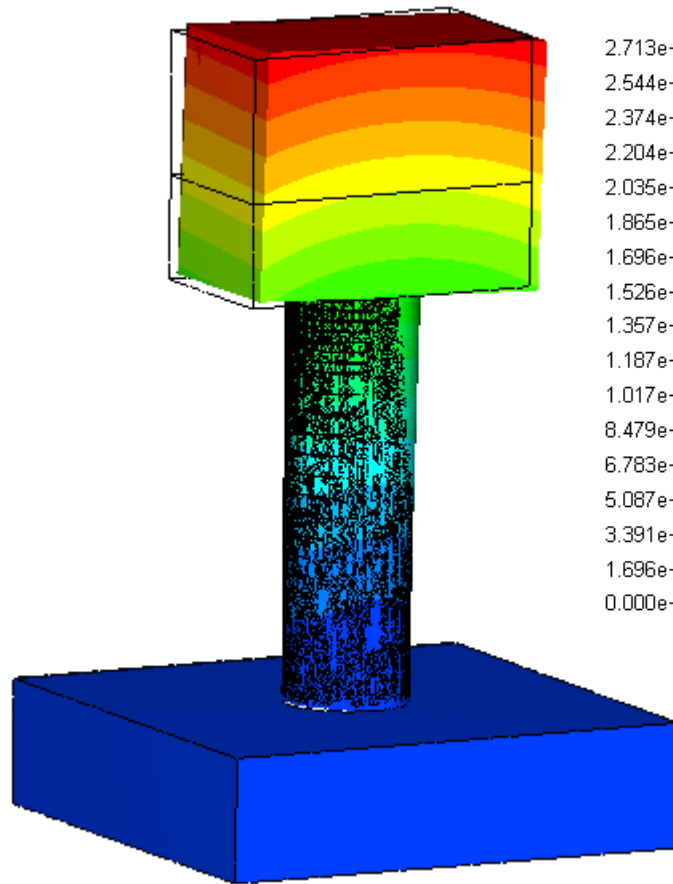


a) steel bar embedded in pier



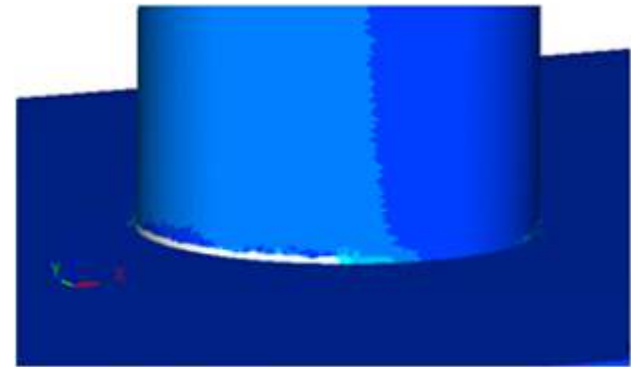
b) surface covered by rectangular elements of 15 x 7.4 mm

TENATIVE RESULTS



a) whole view

2.713e+001
2.544e+001
2.374e+001
2.204e+001
2.035e+001
1.865e+001
1.696e+001
1.526e+001
1.357e+001
1.187e+001
1.017e+001
8.479e+000
6.783e+000
5.087e+000
3.391e+000
1.696e+000
0.000e+000



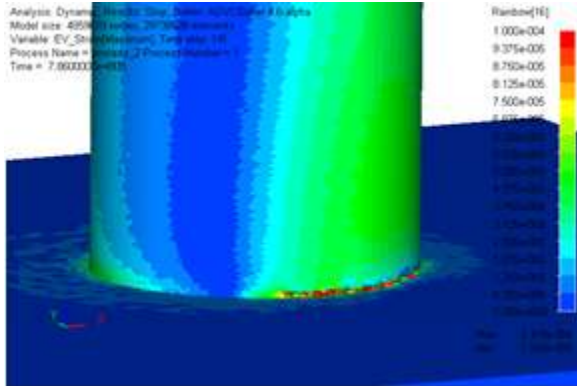
b) connecting part



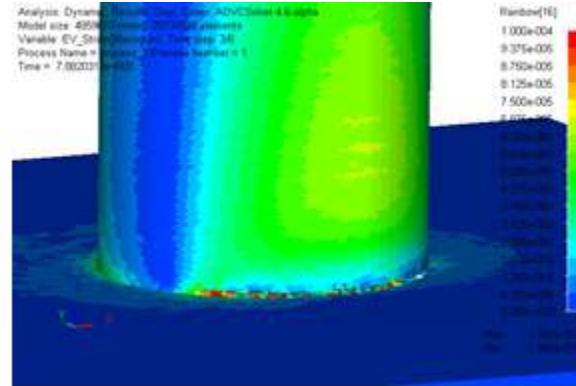
c) cross section at connecting part

TENATIVE RESULTS

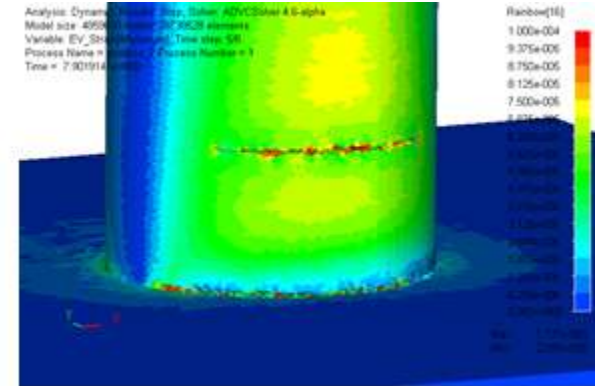
0.86 [s]



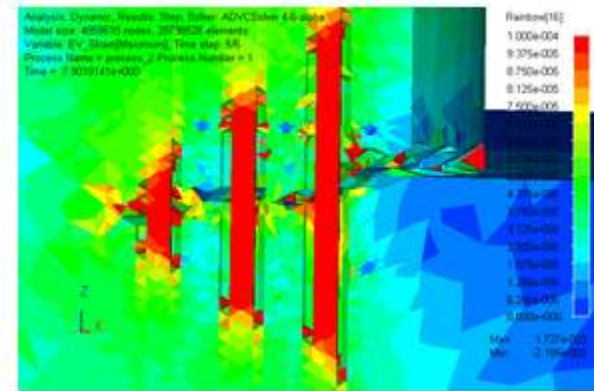
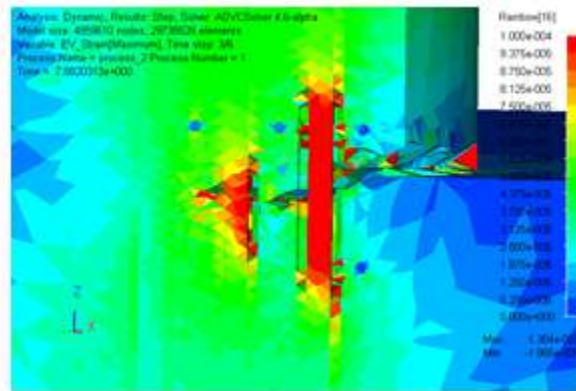
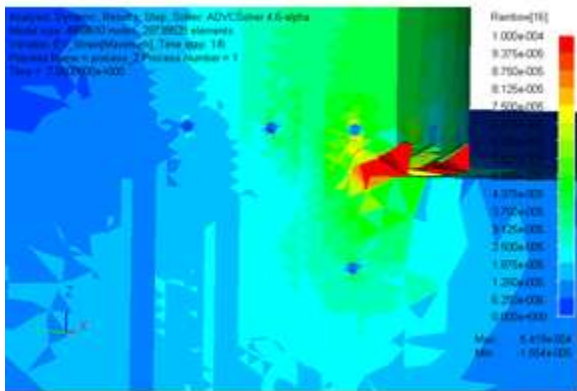
0.88 [s]



0.90 [s]

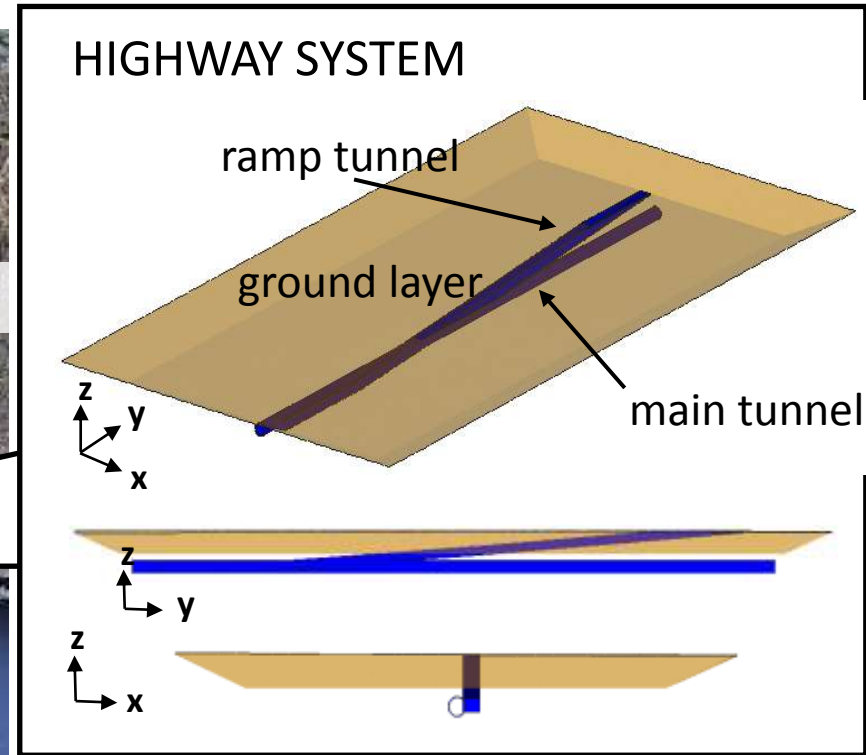
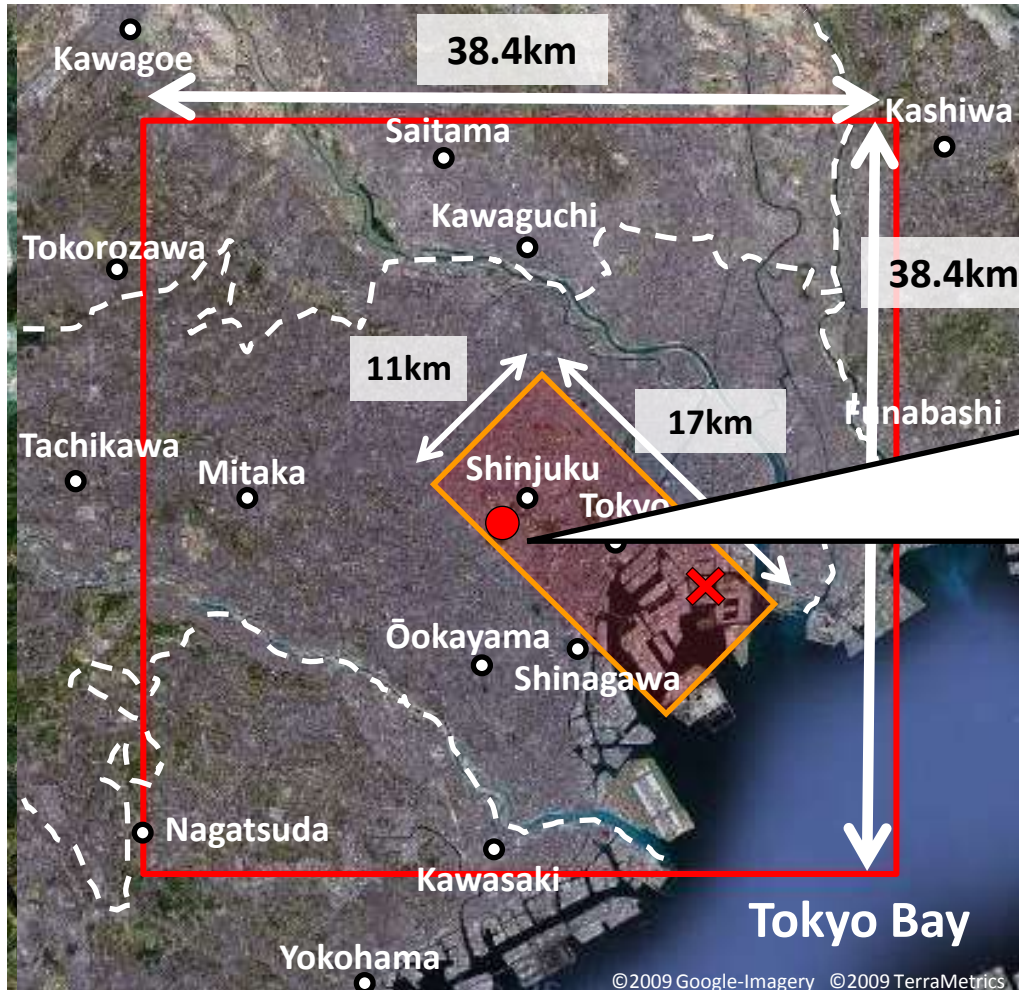


a) surface



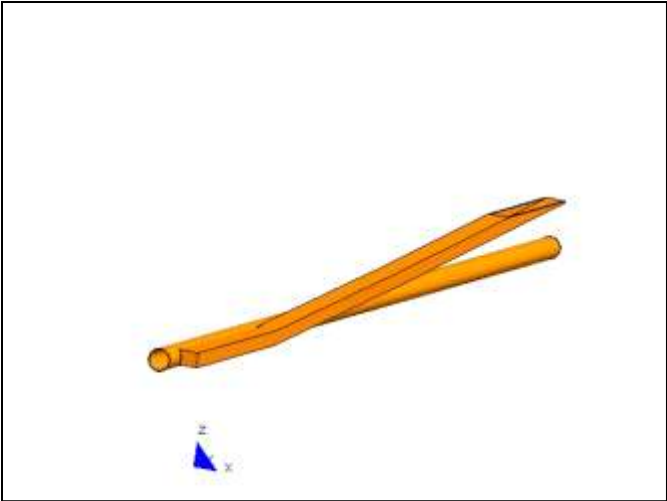
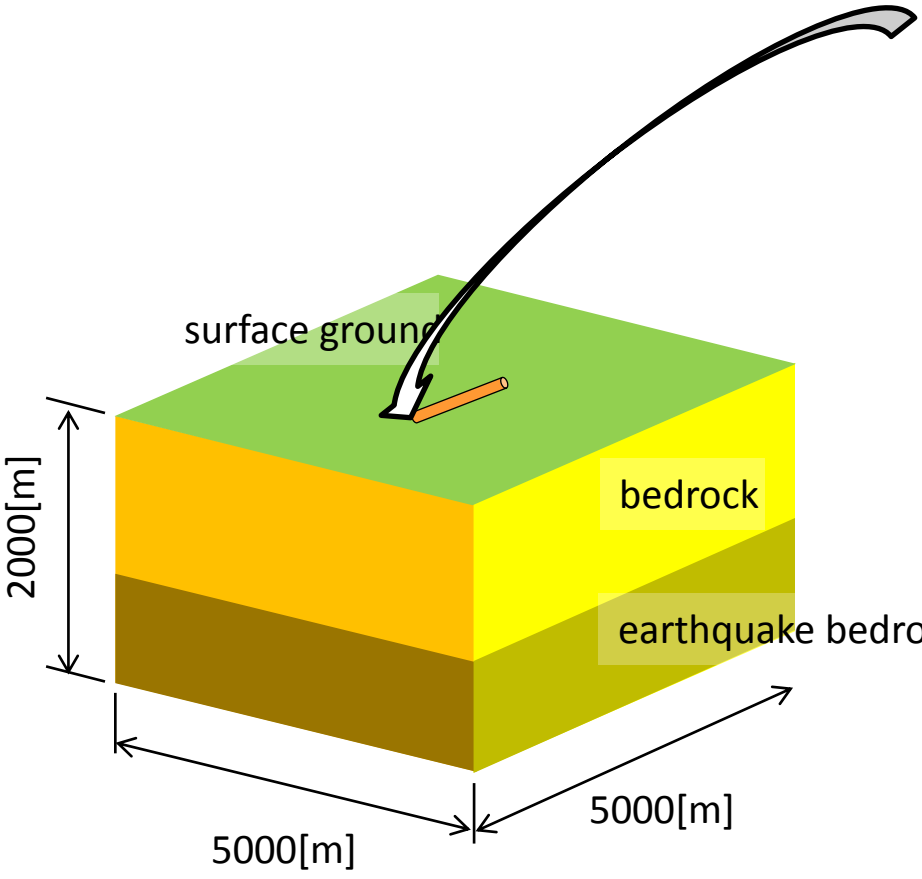
b) stress distribution inside of column

LARGE-SCALE HIGHWAY TUNNEL



- Target domain
- Fault plane
- ✕ Hypocenter
- Target structure

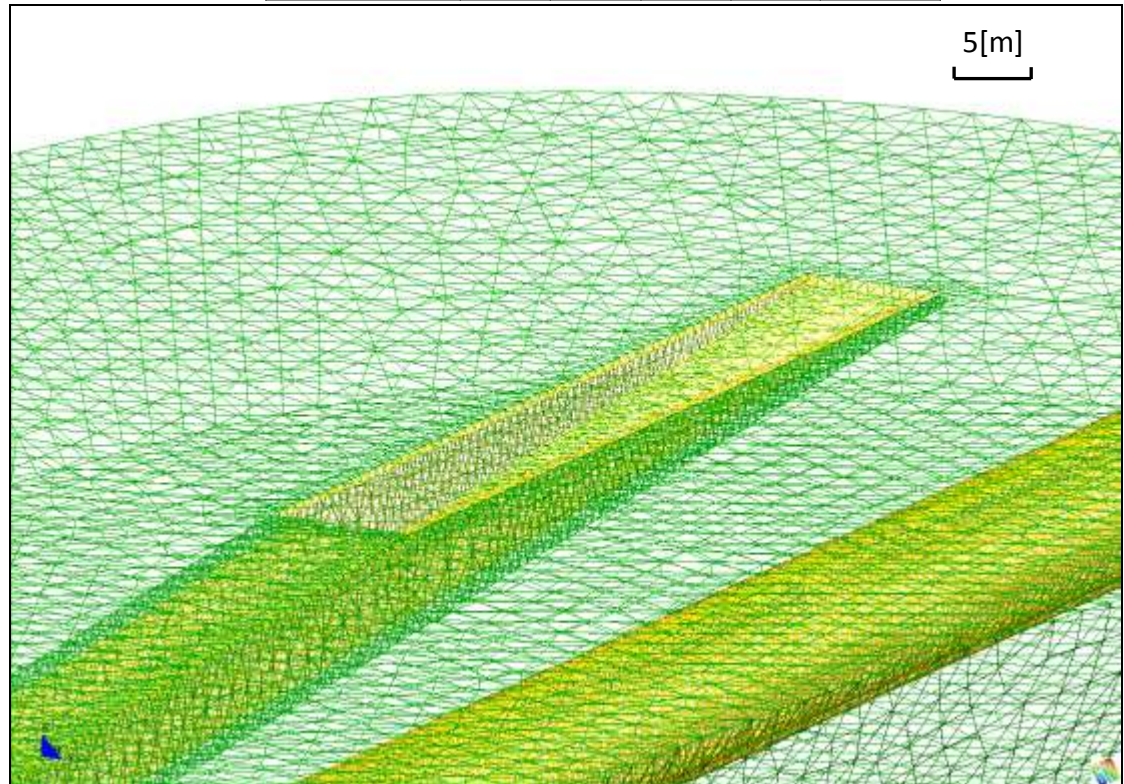
LARGE-SCALE HIGHWAY TUNNEL



ANALYSIS MODEL



	1st layer	2nd layer	3rd layer	4th layer	Tunnel
Vp[m/sec]	1850	2560	3200	5800	3373
Vs[m/sec]	500	1000	1700	3360	2127
density[kg/m ³]	1980	2150	2300	2700	2500
thickness [m]	400	1200	1200	7200	



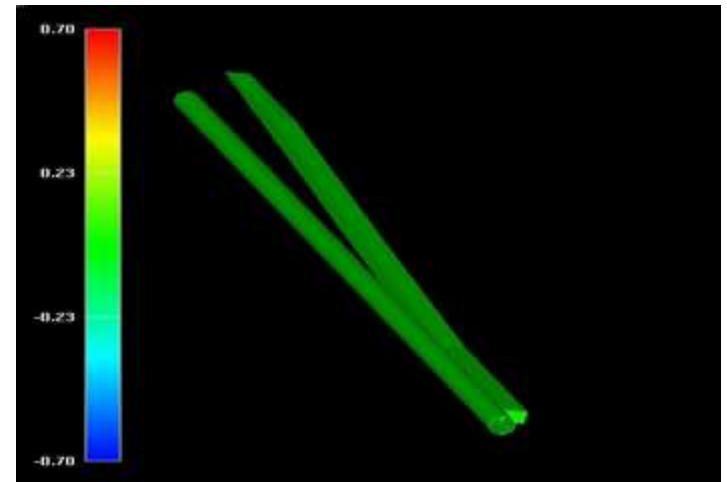
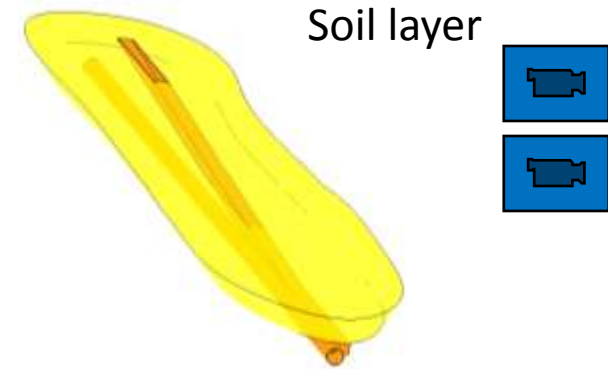
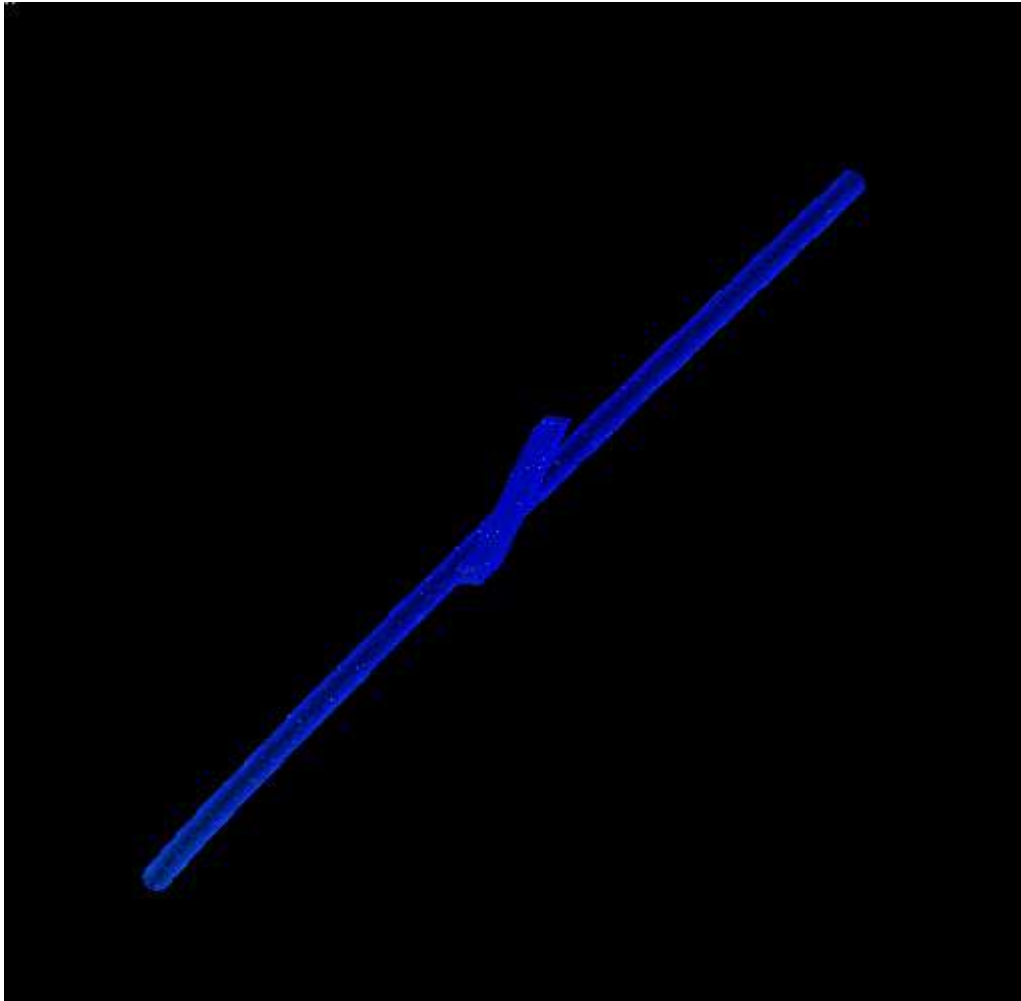
RESULTS: STRUCTURE RESPONSE

Structure response

Filtered (0-0.1, 0.9-1.0)Hz



RESULTS: STRUCTURE RESPONSE



都市のシミュレーション



- 東日本大震災の事例再現

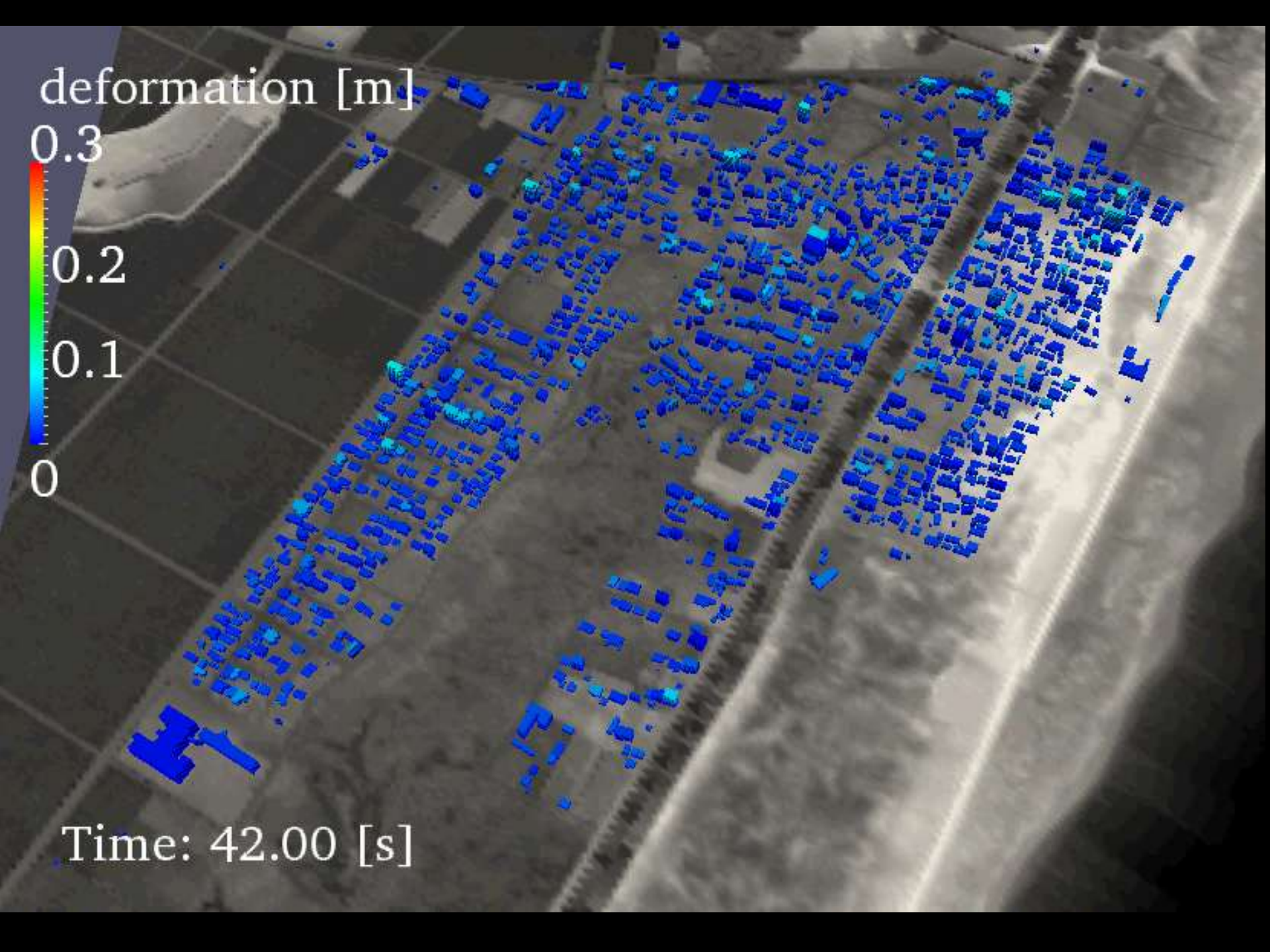


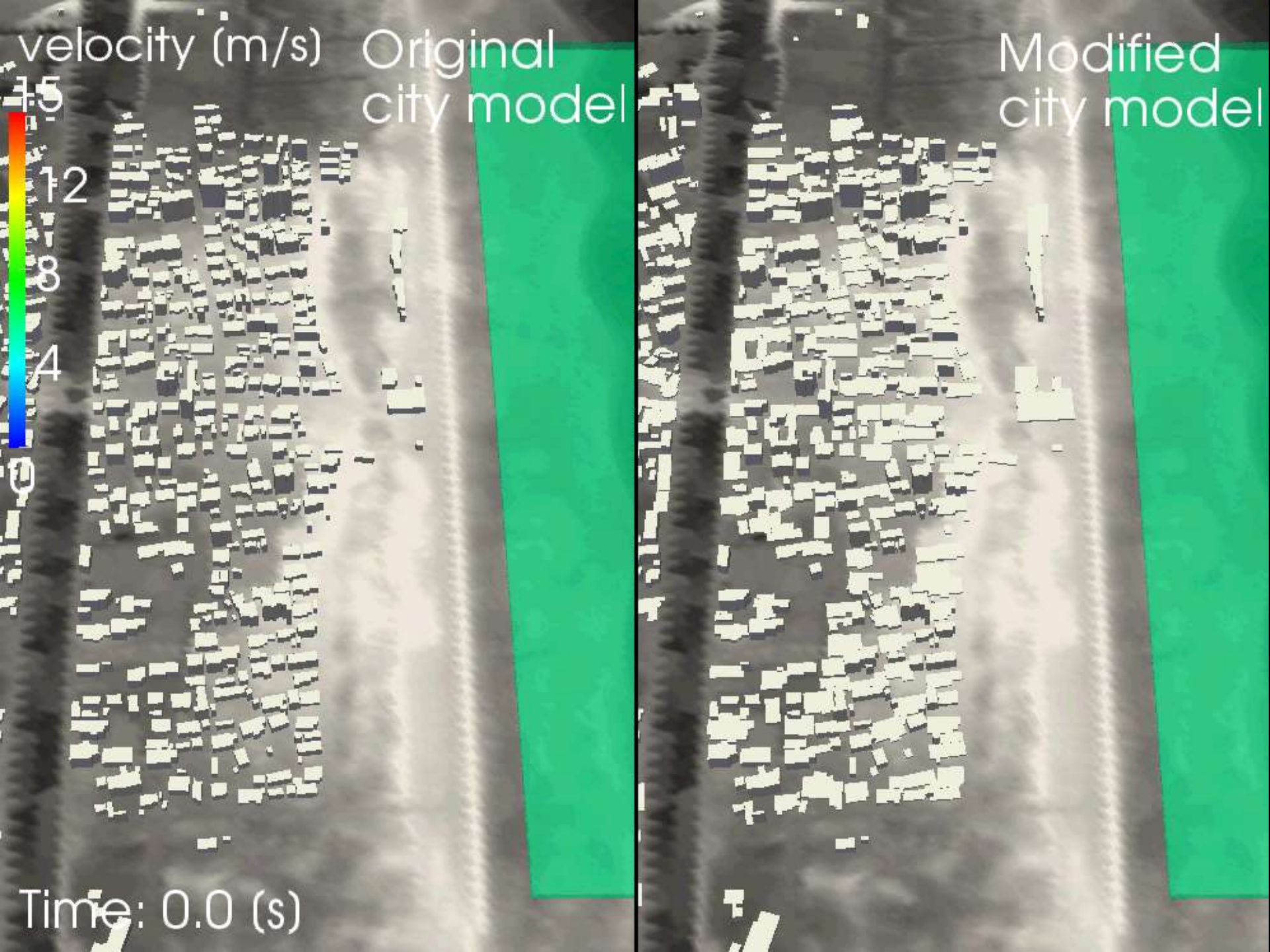
- 首都直下地震の事例予測



- 南海トラフ巨大地震の群衆避難

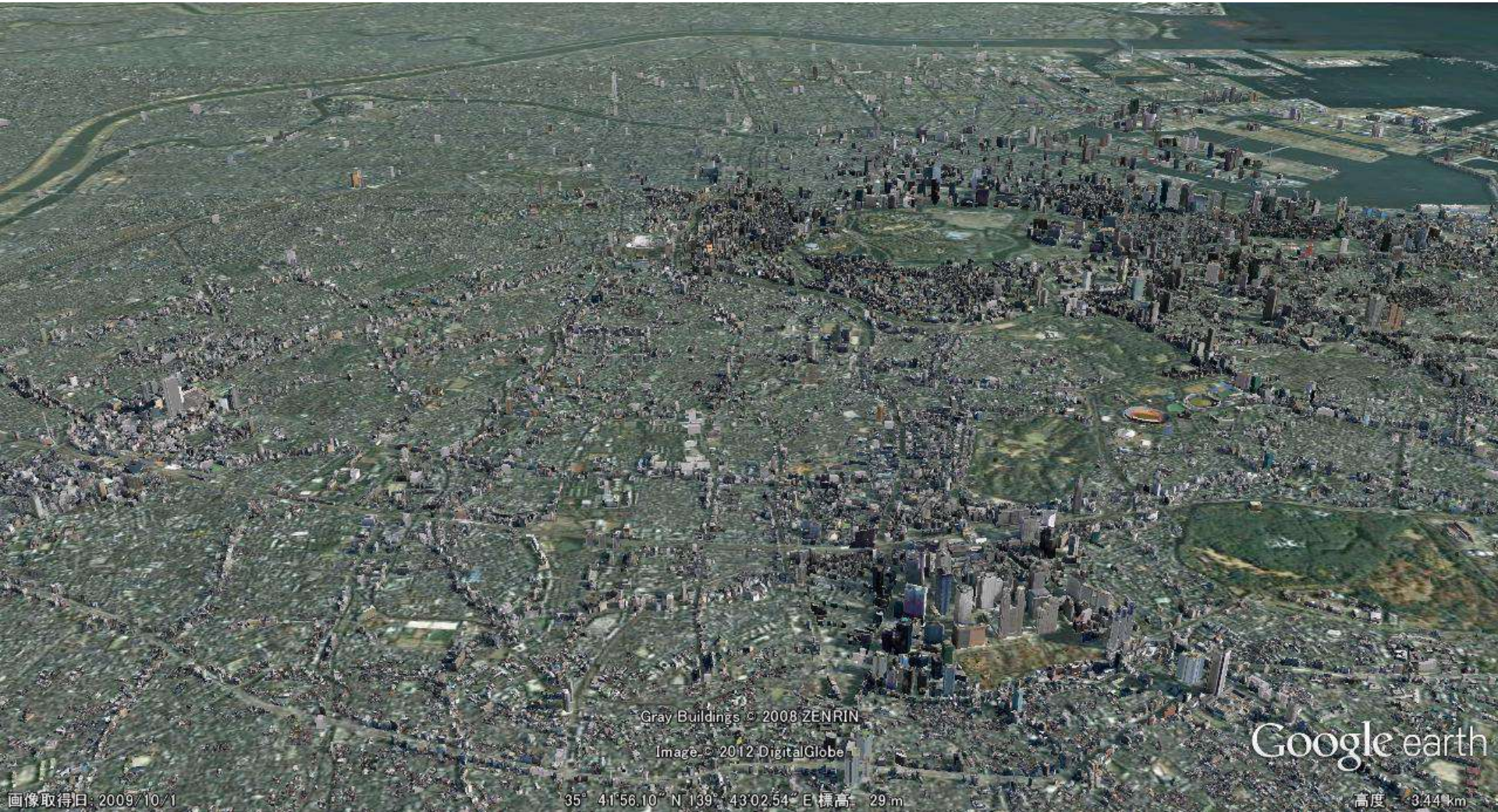






Target Area

Center of Tokyo Metropolis



Gray Buildings © 2008 ZENRIN

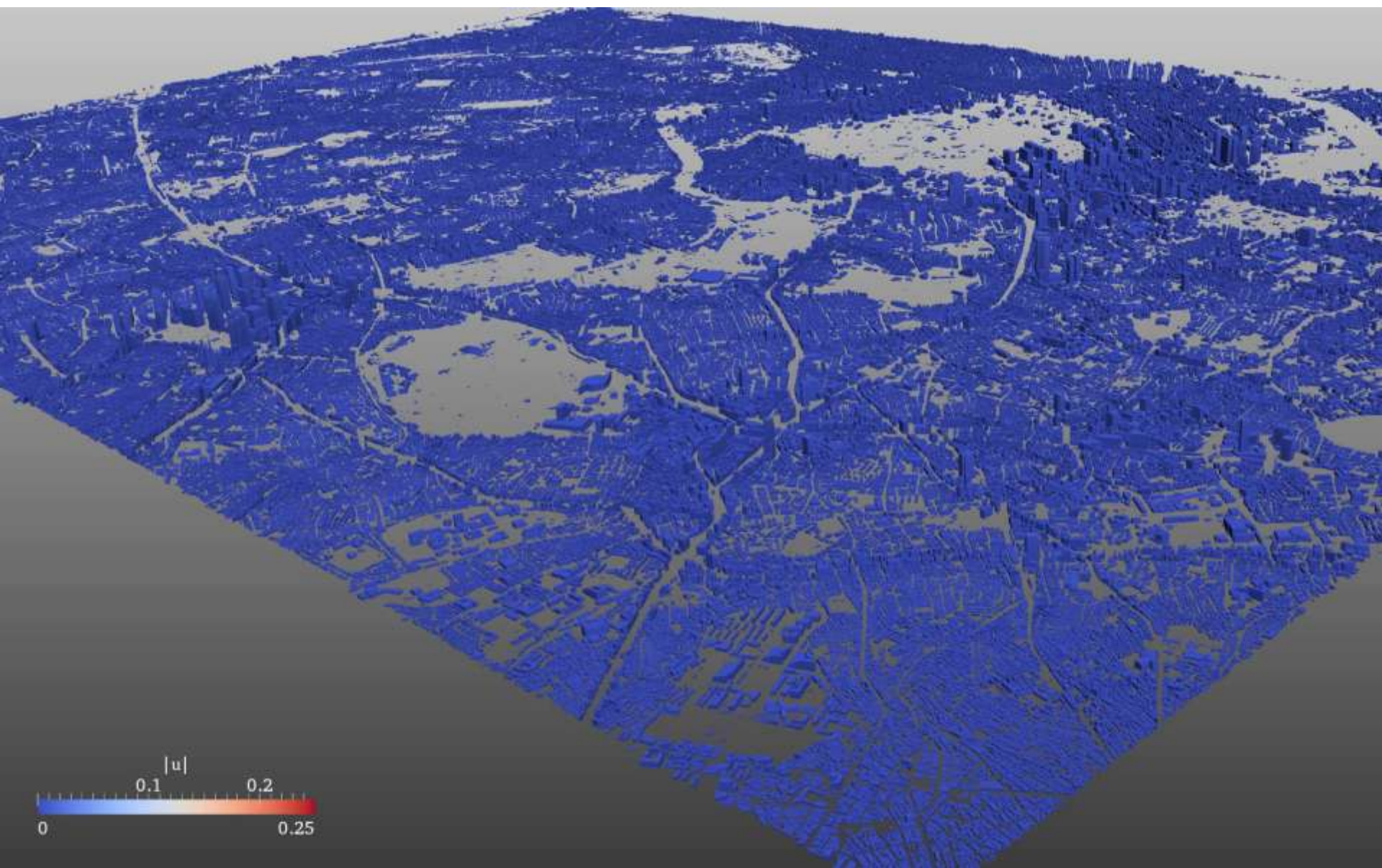
Image © 2012 DigitalGlobe

Google earth

画像取得日: 2009/10/1

35° 41'56.10" N 139° 43'02.54" E 標高: 29 m

高度: 3.44 km



Target Area

Ichigaya



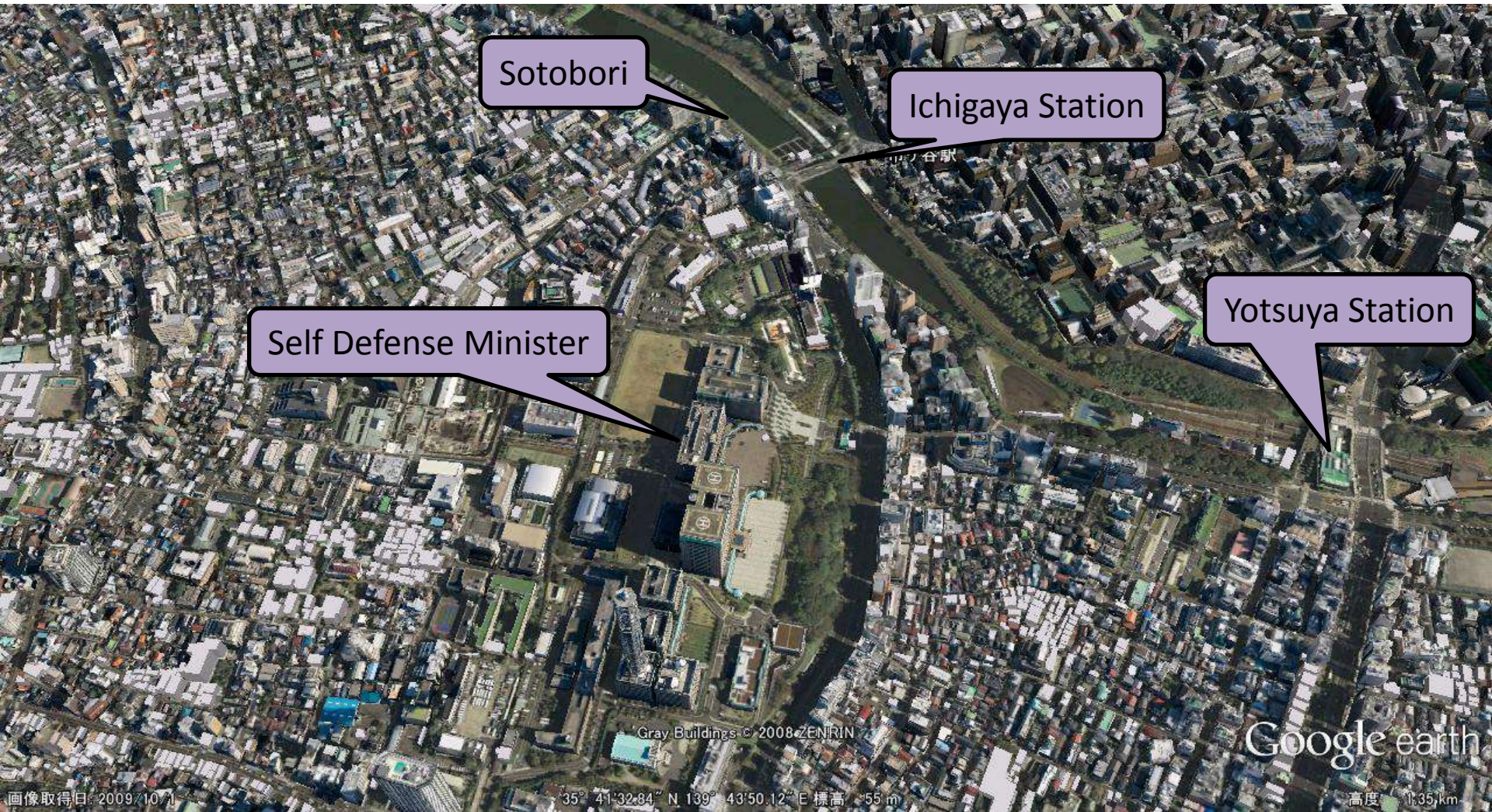
画像取得日: 2009/10/1

35° 41' 32.84" N 139° 43' 50.12" E 標高: 55 m

高度: 1.35 km

Target Area

Ichigaya



Sotobori

Ichigaya Station

Self Defense Minister

Yotsuya Station

Gray Buildings © 2008 ZENRIN

Google earth

35° 41' 32.84" N 139° 43' 50.12" E 標高 55 m

高度 1.35 km

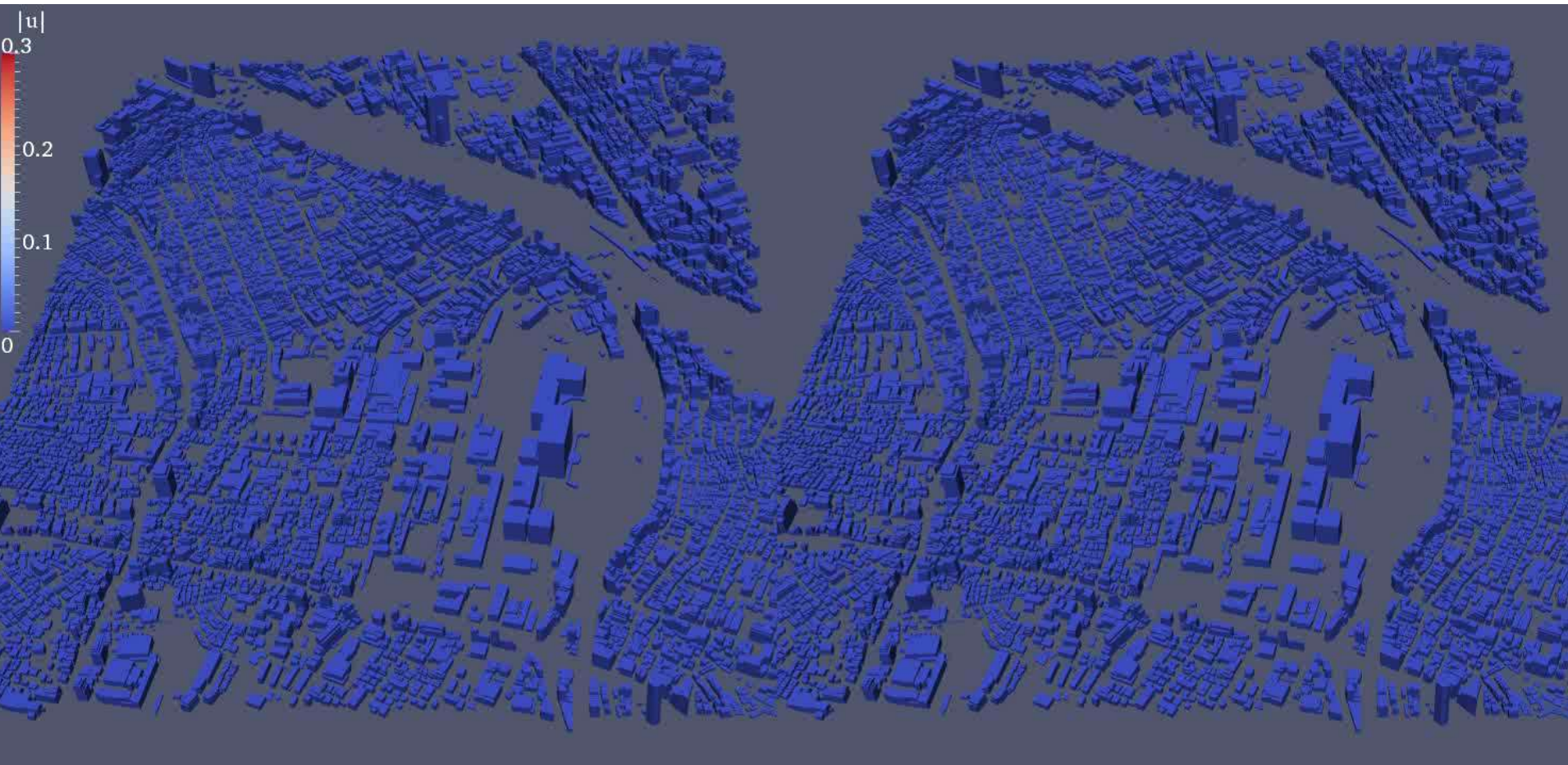
画像取得日: 2009/10/1

Results

Fiber Model (high-rises are not included)

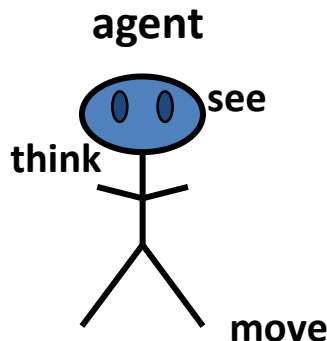
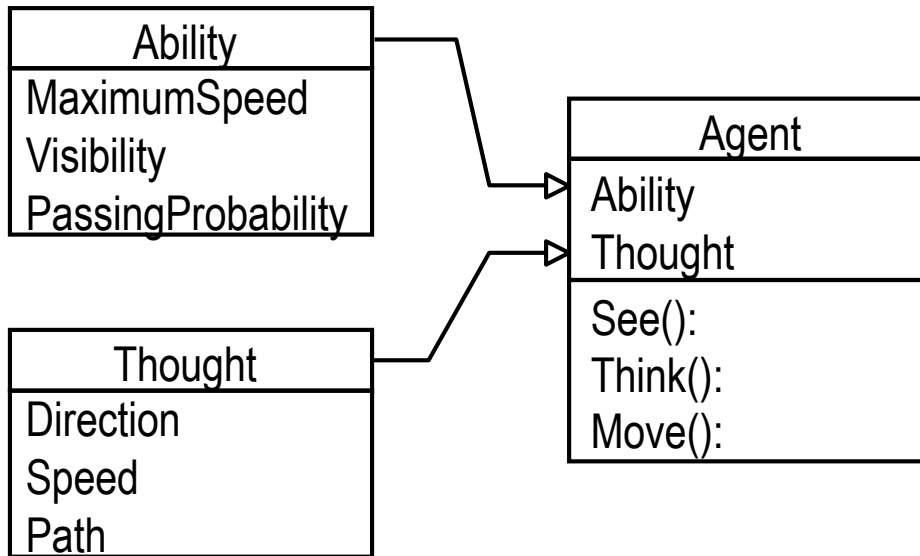
steel bar deterioration considered

steel bar deterioration not considered



DESIGN OF AGENT

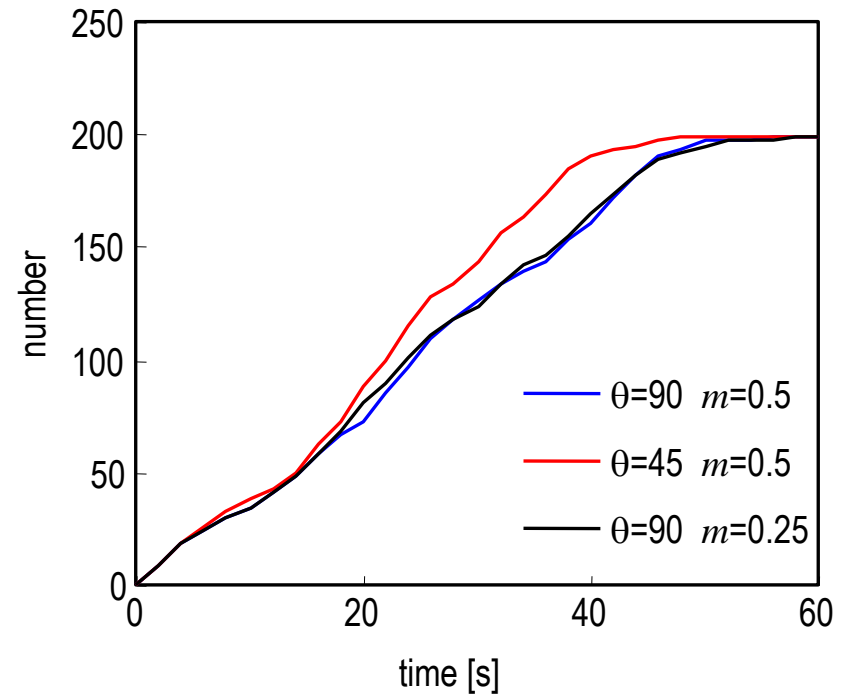
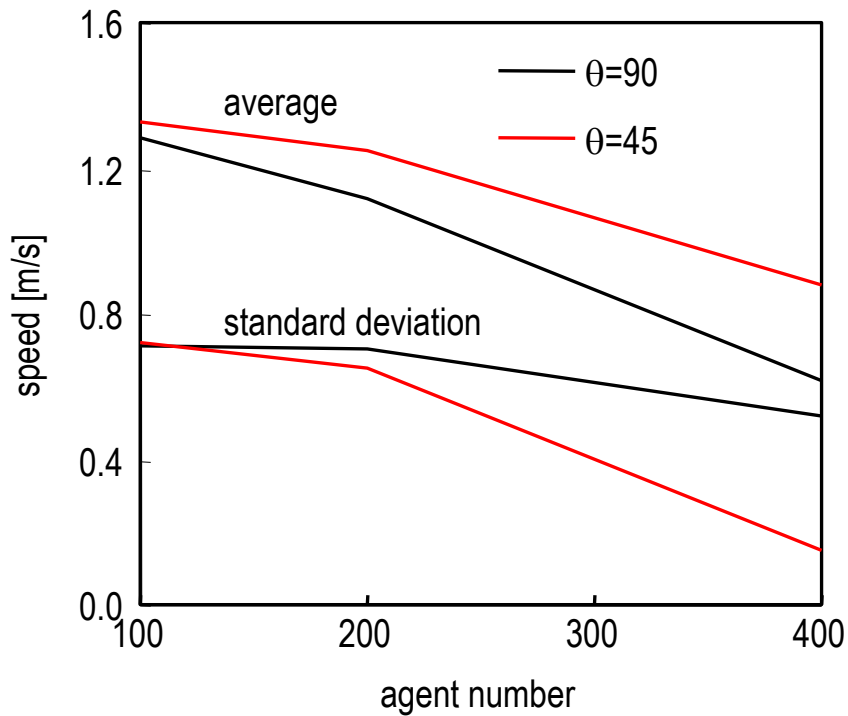
class diagram



parameters

μ	average of agent maximum speed [m/s]
σ	SD of agent maximum speed [m/s]
R	visibility radius [m]
D	dimension of forward domain [m] (domain: $D \times 2D$)
m	speed reduction rate in passing
θ	modification of moving angle in passing [deg]
P	probability of making forced passing

BASIC CHARACTERISTICS OF AGENT



YOKOHAMA CITY FIREWORK FESTIVAL



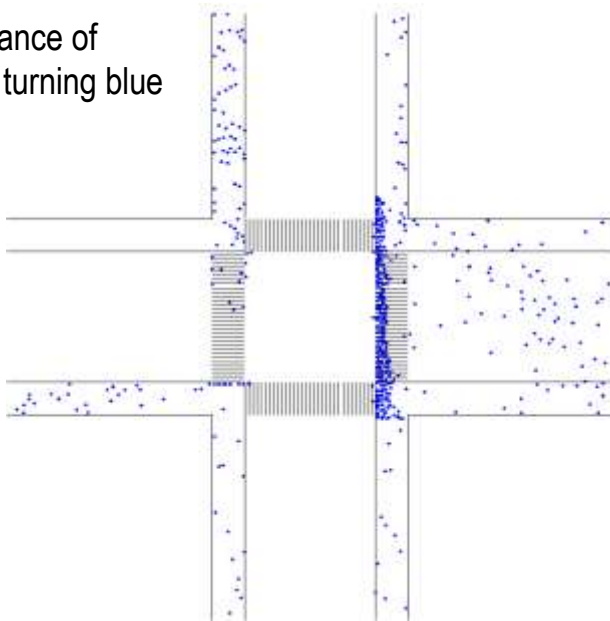
YOKOHAMA CITY FIREWORK FESTIVAL

locus of running person

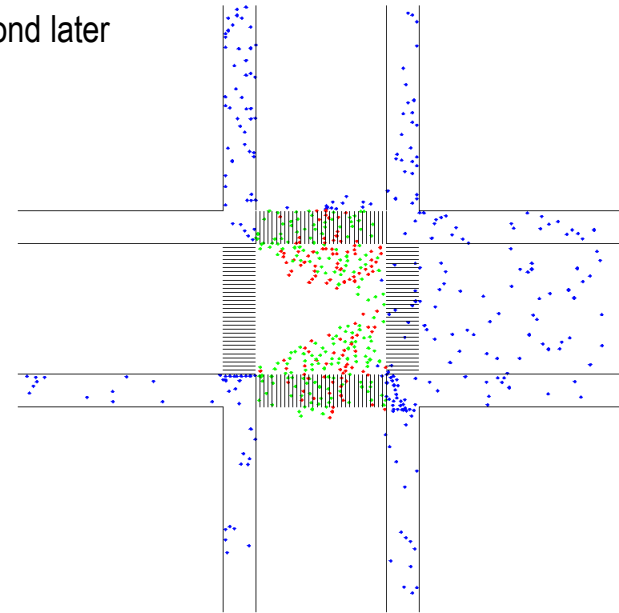
Reproduction/prediction of walking speed distribution, using image analysis of walking people captured by a video camera



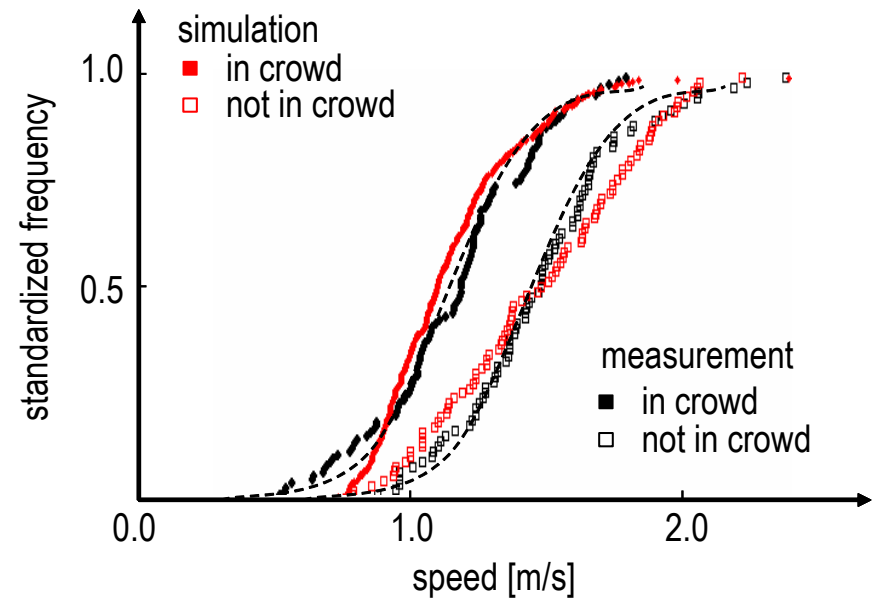
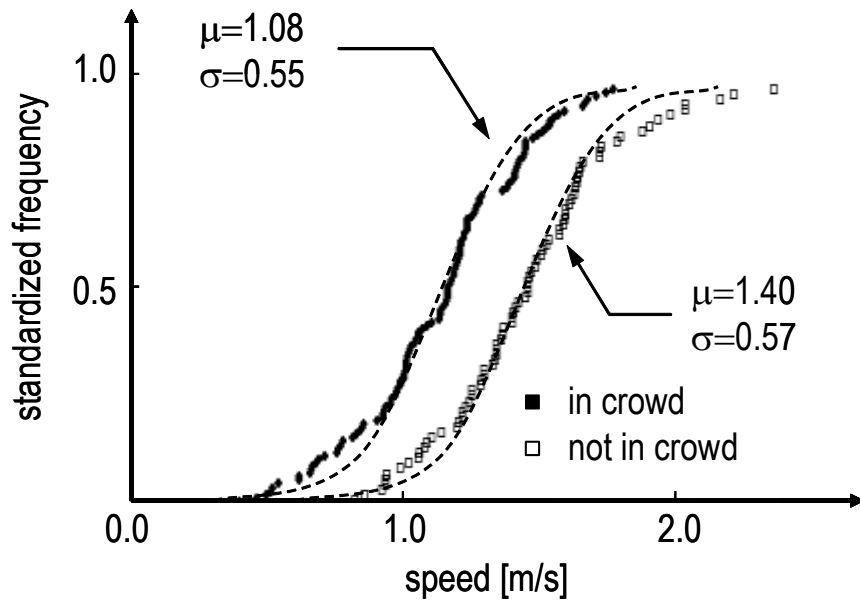
at instance of signal turning blue



10 second later



DISTRIBUTION OF WALKING SPEED



	measured value		simulation	
	in crowd	not in crowd	in crowd	not in crowd
mean [m/s]	1.08	1.40	1.06	1.39
S.D. [m/s]	0.55	0.57	0.51	0.59

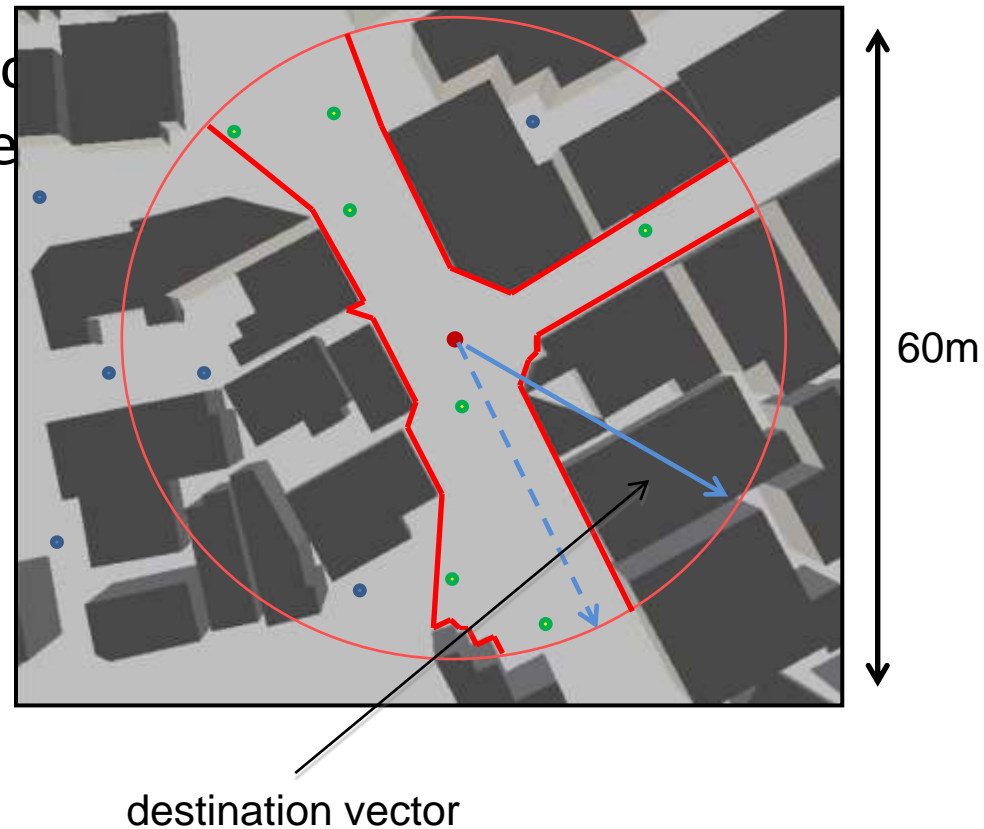
MULTI-AGENT SIMULATION



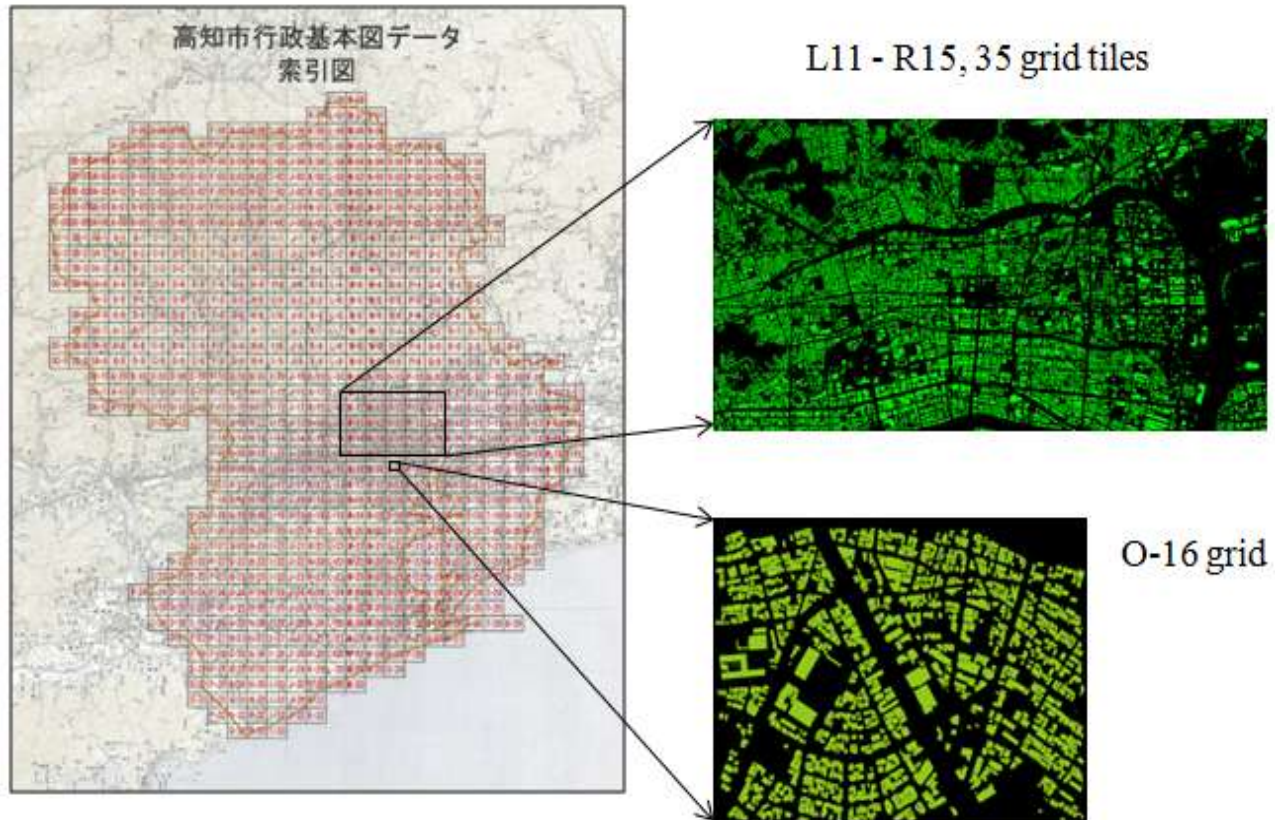
- KISS Principle
from “Keep It Simple, Stupid” to
“Keep It Smart and Sophisticated”

- Agent functionalities
 - see environment
 - see agent
 - think terminal
 - think open space
 - move speed
 - move take-over/pose

agent visibility

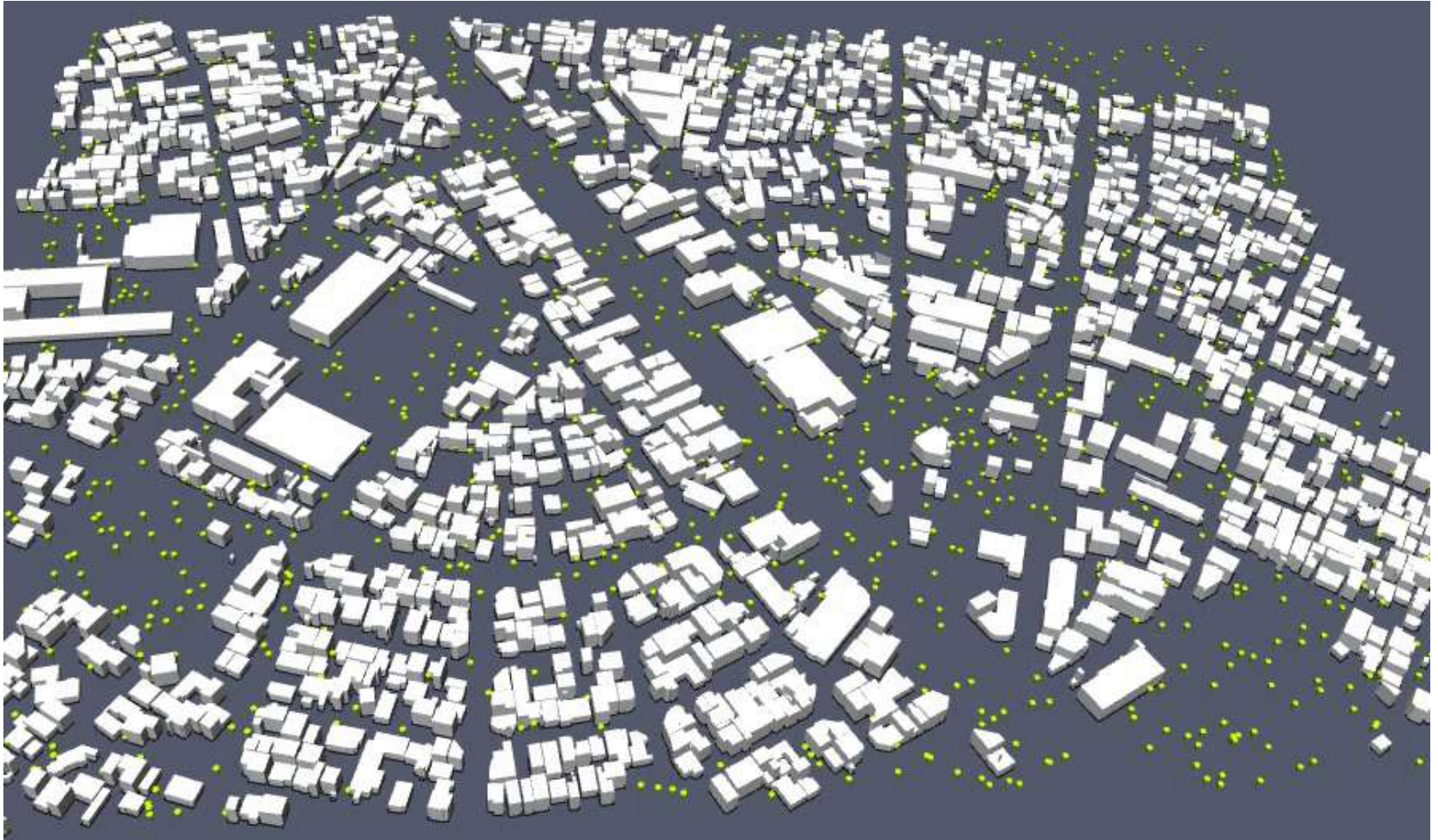


TARGET AREA

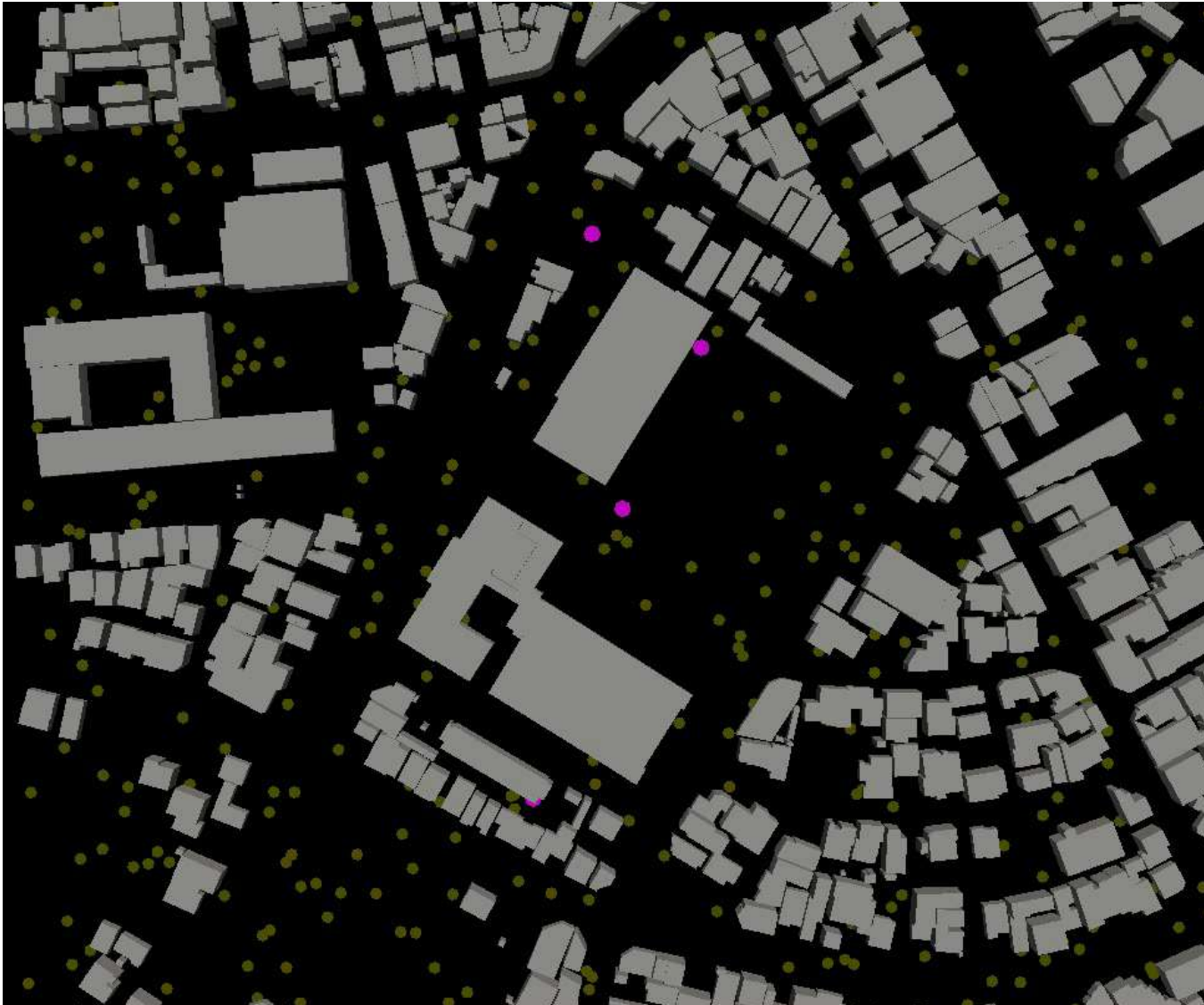


- O-16 grid 1,000 2,080 /km²
- L11-R15 grid 10,000 595 /km²
- 20,000 1,100 /km²

IMPROVEMENT OF AGENT NAVIGATION



INTRODUCTION OF OFFICIAL AGENT



おわりに

- 構造物のシミュレーション
 - 基礎研究
 - 詳細モデルの構築と超高性能解析
- 都市のシミュレーション
 - 統合技術
 - 複合災害：地震動と津波，被害と対応