シミュレーションが未来をひらく

Social simulation with supercomputers

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and
Discrete-Event Simulation Research Team, Riken Center for Computational Science

1. Cooperation strategy
2. Traffic simulations
3. Disaster simulations
4. Remarks

Collaboration with
Yuta Asano, Tetsuro Imai, Hajime Inaoka, Yohsuke Murase, Takeshi Uchitane, Shih-Chieh Wang , and Naoki Yoshioka (RIKEN AICS)
Takashi Shimada, Naoki Yoshioka, Koji Oishi, Takayuki Hiraoka, Masaru Nagumo (U. Tokyo)
and CREST CASSIA and PostK-MultiSESIM teams:
Itsuki Noda(AIST), Kiyoshi Izumi and Hideki Fujii(UT), Mitsuhiro Hattori(Ritsumeikan U.),
Sawako Yoshihama and Hideyuki Mizuta(IBM)
Tomio Kamada(Kobe U).
Financial Support
CREST, JST "Post-Peta-scale Project" (2012 – 2017)
MEXT, Japan "Post K Computer Project" (2016 – 2019)

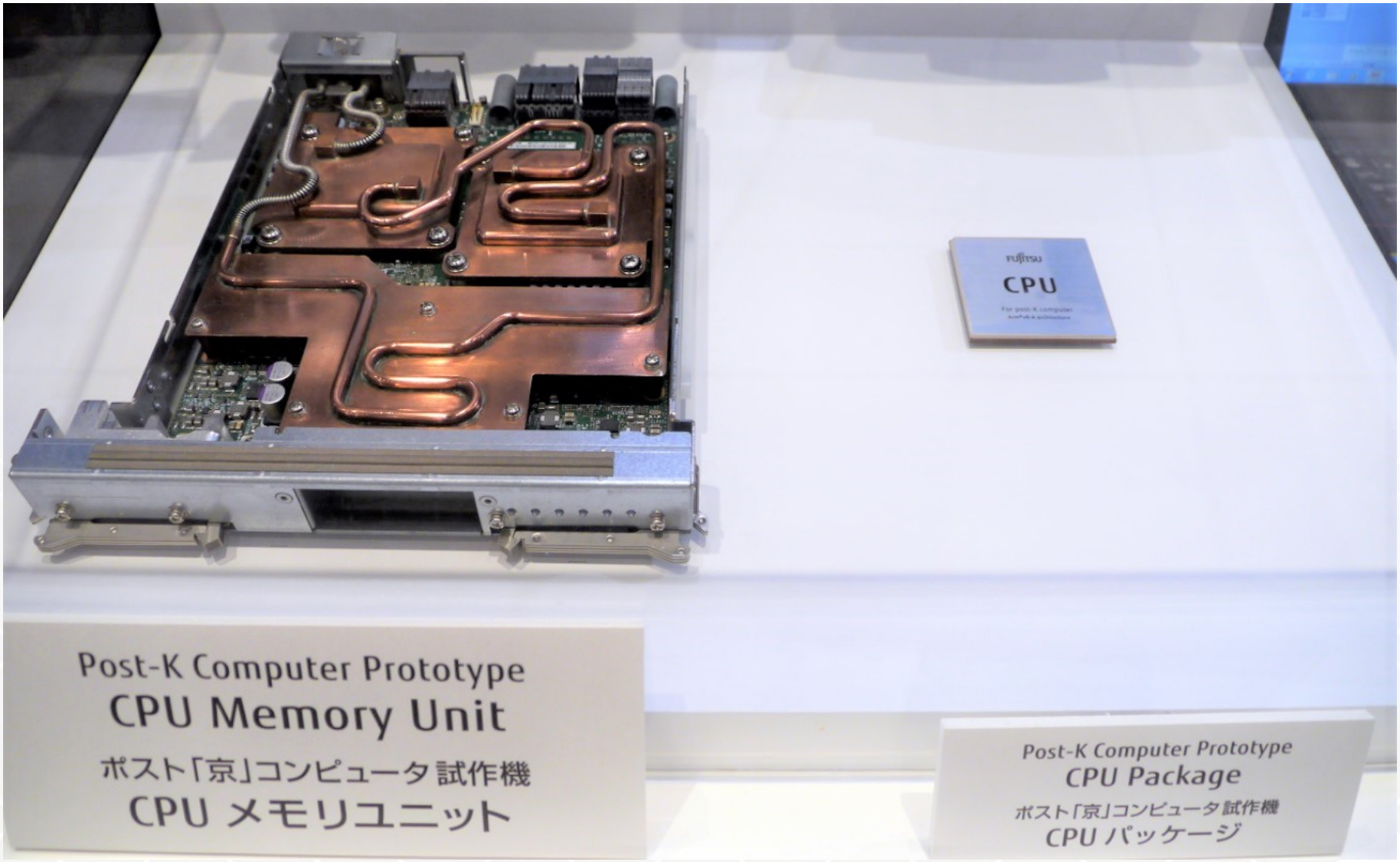
RIKEN AICS and K Computer

シミュレーションが未来をひらく

since 2011 till 2019

computer area: 10500m²
human area: 9000m²
cooling machine area: 1900m²

432 cabinets = 864 racks = 82,944computation nodes + 5,184 I/O nodes 216 disk racks
10.75PFLOPS, main memery 1.27PB, disk 11PB


FUJITSU
CPU
Post-K Computer Prototype
CPU Memory Unit
ポスト「京」コンピュータ試作機
CPU メモリユニット
Post-K Computer Prototype
CPU Package
ポスト「京」コンピュータ試作機
CPU パッケージ

A64FX Chip Overview

FUJITSU

Architecture Features

- Armv8.2-A (AArch64 only)
- SVE 512-bit wide SIMD
- 48 computing cores + 4 assistant cores*

*All the cores are identical

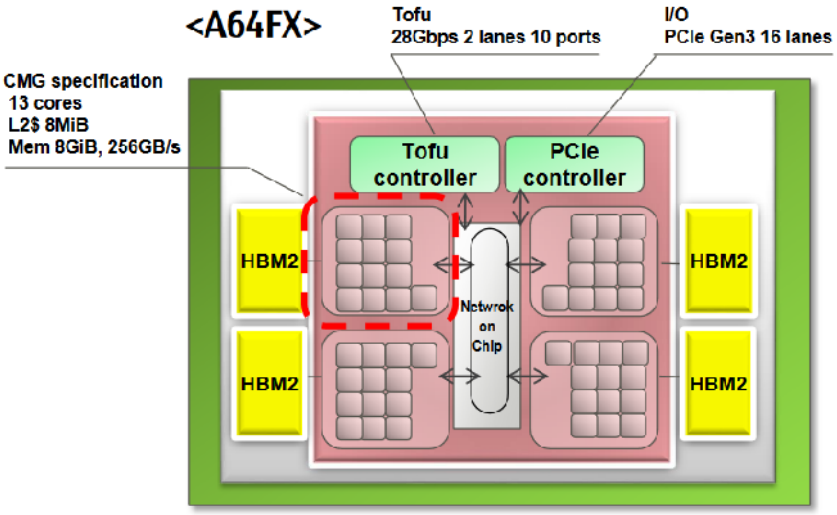
- HBM2 32GiB
- Tofu 6D Mesh/Torus
  28Gbps x 2 lanes x 10 ports
- PCIe Gen3 16 lanes

7nm FinFET

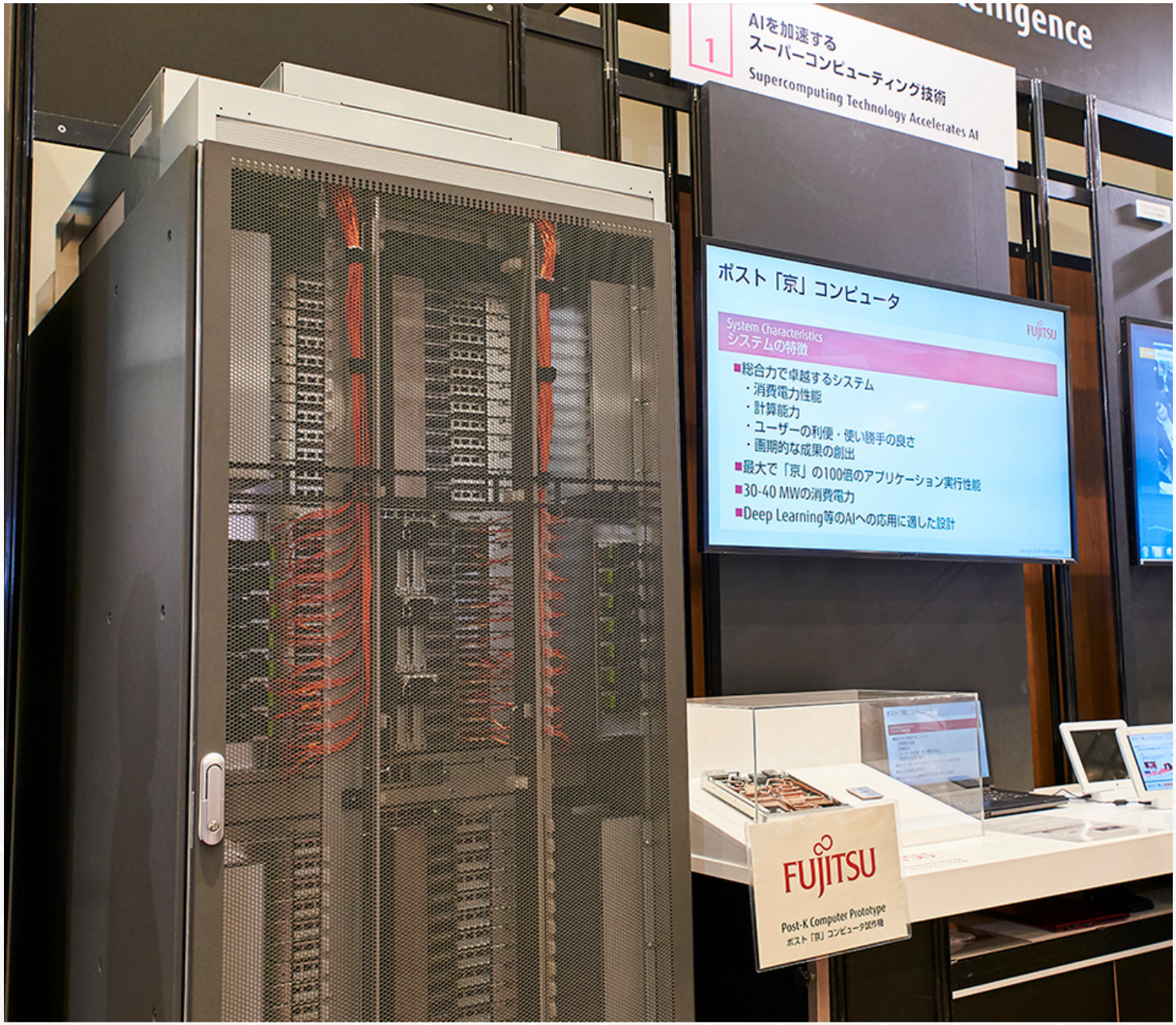
- 8,786M transistors
- 594 package signal pins

Peak Performance (Efficiency)

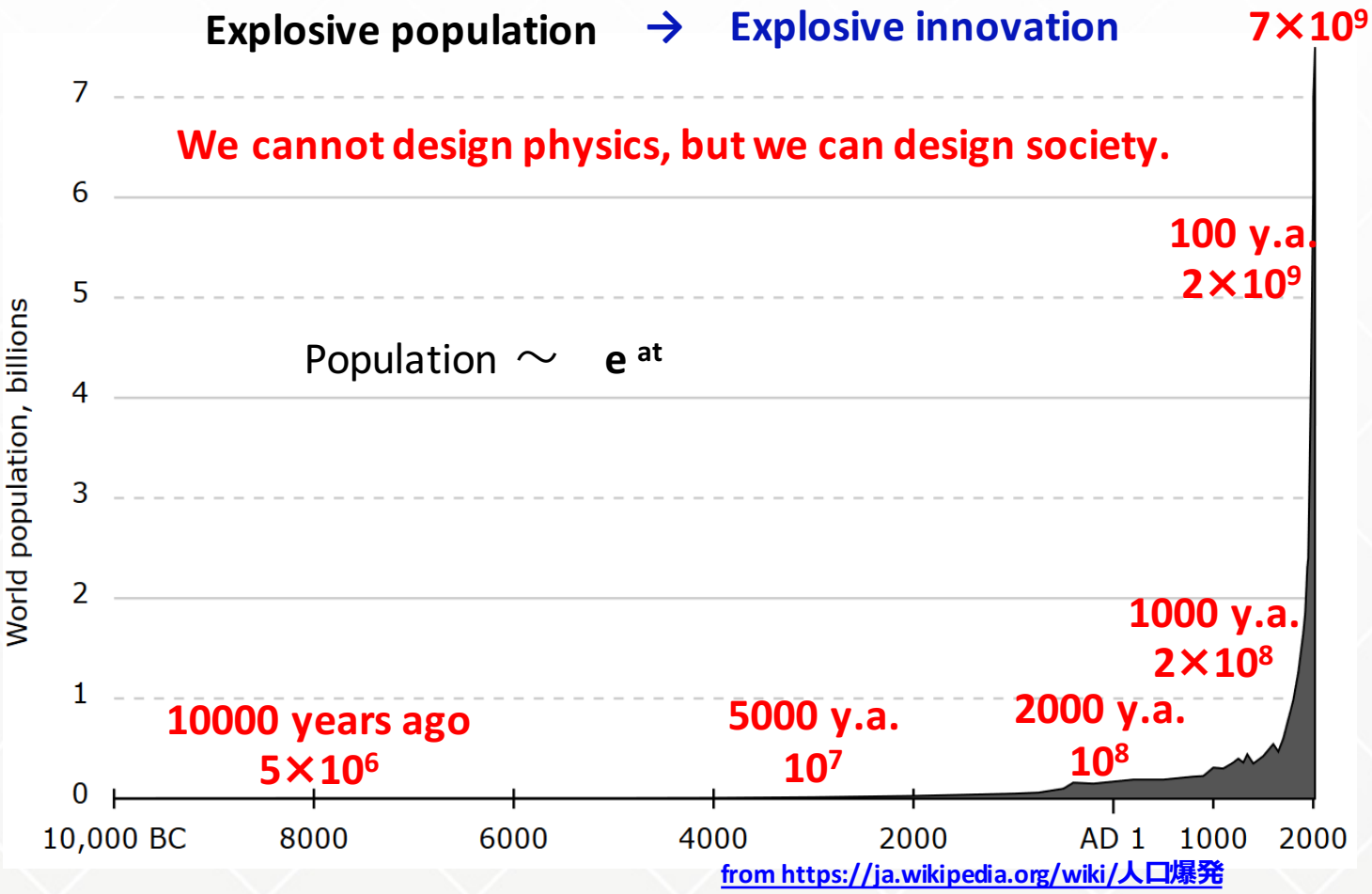
- >2.7TFLOPS (>90%@DGEMM)
- Memory B/W 1024GB/s (>80%@Stream Triad)



	A64FX (Post-K)	SPARC64 XIfx (PRIMEHPC FX100)
ISA (Base)	Armv8.2-A	SPARC-V9
ISA (Extension)	SVE	HPC-ACE2
Process Node	7nm	20nm
Peak Performance	>2.7TFLOPS	1.1TFLOPS
SIMD	512-bit	256-bit
# of Cores	48+4	32+2
Memory	HBM2	HMC
Memory Peak B/W	1024GB/s	240GB/s x2 (in/out)


1
AIを加速する
スーパーコンピューティング技術
Supercomputing Technology Accelerates AI
ポスト「京」コンピュータ
System Characteristics
システムの特徴
FUJITSU
■総合力で卓越するシステム
・消費電力性能
・計算能力
・ユーザーの利便・使い勝手の良さ
・画期的な成果の創出
■最大で「京」の100倍のアプリケーション実行性能
■30-40 MWの消費電力
■Deep Learning等のAIへの応用に適した設計
FUJITSU
Post-K Computer Prototype
ポスト「京」コンピュータ試作機

HPC and ITC, Holy Grail? No, global human ties will be one.

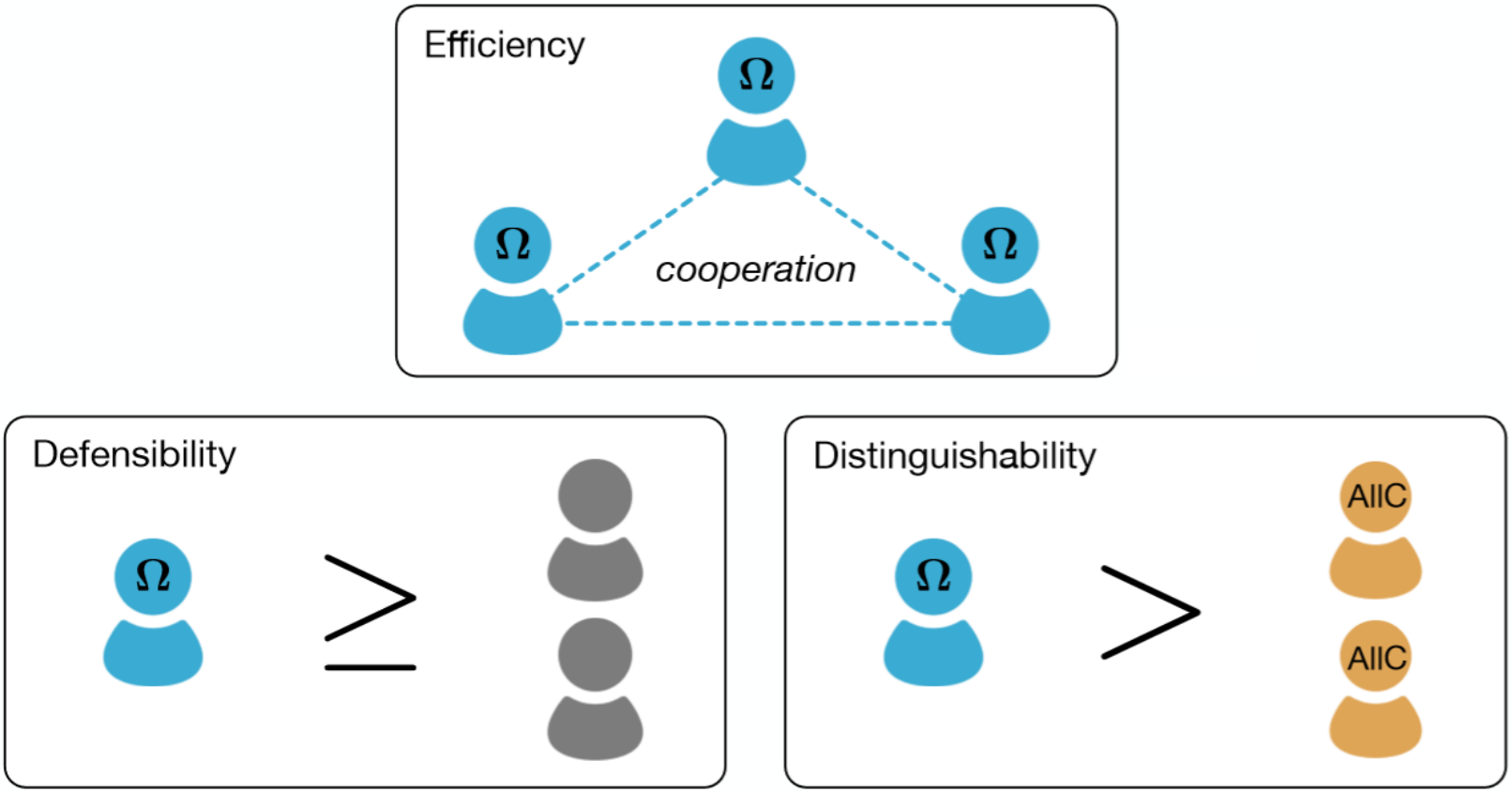


from https://ja.wikipedia.org/wiki/人口爆発

Way to global cooperative society

The K computer found
an efficient, defensible and distinguishable strategy
for repeated prisoner's dilemma game
in three agents with three step memory

Y. Murase and S. K. Baek, J. Theor. Biol. 449 p.94 (2018).



$B_{t-3}B_{t-2}B_{t-1}C_{t-3}C_{t-2}C_{t-1}$	$A_{t-3}A_{t-2}A_{t-1}$							
	ccc	*ccd*	*cdc*	*cdd*	*dcc*	*dcd*	*ddc*	*ddd*
cccccc	*c*	*c*	*d*	*c*	*c*	*c*	*d*	*c*
ccccd/ccdccc	*d*	*c*	*c*	*c*	*d*	*c*	*c*	*c*
ccccdc/cdcccc	*c*	*d*	*c*	*d*	*c*	*d*	*c*	*d*
ccccdd/cddccc	*d*	*d*	*d*	*d*	*d*	*d*	*d*	*d*
cccdcc/dccccc	*c*	*c*	*d*	*c*	*c*	*c*	*d*	*c*
cccdcd/dcdccc	*d*	*c*	*c*	*c*	*d*	*c*	*c*	*c*
cccddc/ddcccc	*c*	*d*	*c*	*d*	*c*	*d*	*c*	*d*
cccddd/dddccc	*d*	*d*	*d*	*d*	*d*	*d*	*d*	*d*
ccdccd	*d*	*c*	*c*	*c*	*d*	*c*	*c*	*d*
ccdcdc/cdcccd	*c*	*c*	*c*	*c*	*d*	*c*	*d*	*c*
ccdcdd/cddccd	*d*	*d*	*d*	*d*	*d*	*d*	*d*	*d*
ccddcc/dccccd	*d*	*c*	*c*	*c*	*d*	*c*	*c*	*c*
ccddcd/dcdccd	*d*	*c*	*c*	*d*	*d*	*c*	*c*	*d*
ccdddc/ddcccd	*d*	*c*	*d*	*c*	*d*	*c*	*d*	*c*
ccdddd/dddccd	*d*	*d*	*d*	*d*	*d*	*d*	*d*	*d*
cdccdc	*c*	*d*	*c*	*d*	*c*	*c*	*c*	*d*
cdccdd/cddcdc	*d*	*d*	*c*	*d*	*d*	*d*	*c*	*d*
cdcdcc/dcccdc	*c*	*d*	*c*	*c*	*c*	*d*	*c*	*d*
cdcdcd/dcdcdc	*d*	*c*	*d*	*c*	*d*	*c*	*d*	*c*
cdcddc/ddccdc	*c*	*d*	*c*	*d*	*c*	*d*	*c*	*d*
cdcddd/dddcdc	*d*	*d*	*c*	*d*	*d*	*d*	*c*	*d*
cddcdd	*d*	*d*	*c*	*d*	*d*	*d*	*c*	*d*
cdddcc/dcccdd	*d*	*d*	*d*	*d*	*d*	*d*	*d*	*d*
cdddcd/dcdcdd	*d*	*d*	*d*	*d*	*d*	*d*	*d*	*d*
cddddc/ddccdd	*d*	*d*	*c*	*c*	*d*	*d*	*c*	*d*
cddddd/dddcdd	*d*	*d*	*c*	*d*	*d*	*d*	*c*	*d*
dccdcc	*c*	*c*	*d*	*c*	*c*	*c*	*d*	*c*
dccdcd/dcddcc	*d*	*c*	*c*	*c*	*d*	*c*	*c*	*c*
dccddc/ddcdcc	*c*	*d*	*c*	*d*	*c*	*d*	*c*	*d*
dccddd/ddddcc	*d*	*d*	*d*	*d*	*d*	*d*	*d*	*d*
dcddcd	*d*	*c*	*c*	*d*	*d*	*c*	*c*	*d*
dcdddc/ddcdcd	*d*	*c*	*d*	*c*	*d*	*c*	*d*	*c*
dcdddd/dddddcd	*d*	*d*	*d*	*d*	*d*	*d*	*d*	*d*
ddcddc	*c*	*d*	*c*	*d*	*c*	*d*	*c*	*d*
ddcddd/dddddc	*d*	*d*	*c*	*d*	*d*	*d*	*c*	*d*
dddddd	*d*	*d*	*c*	*d*	*d*	*d*	*c*	*d*

Three agent with memory three:
totally $2^{288} \simeq 5\times10^{86}$ strategies

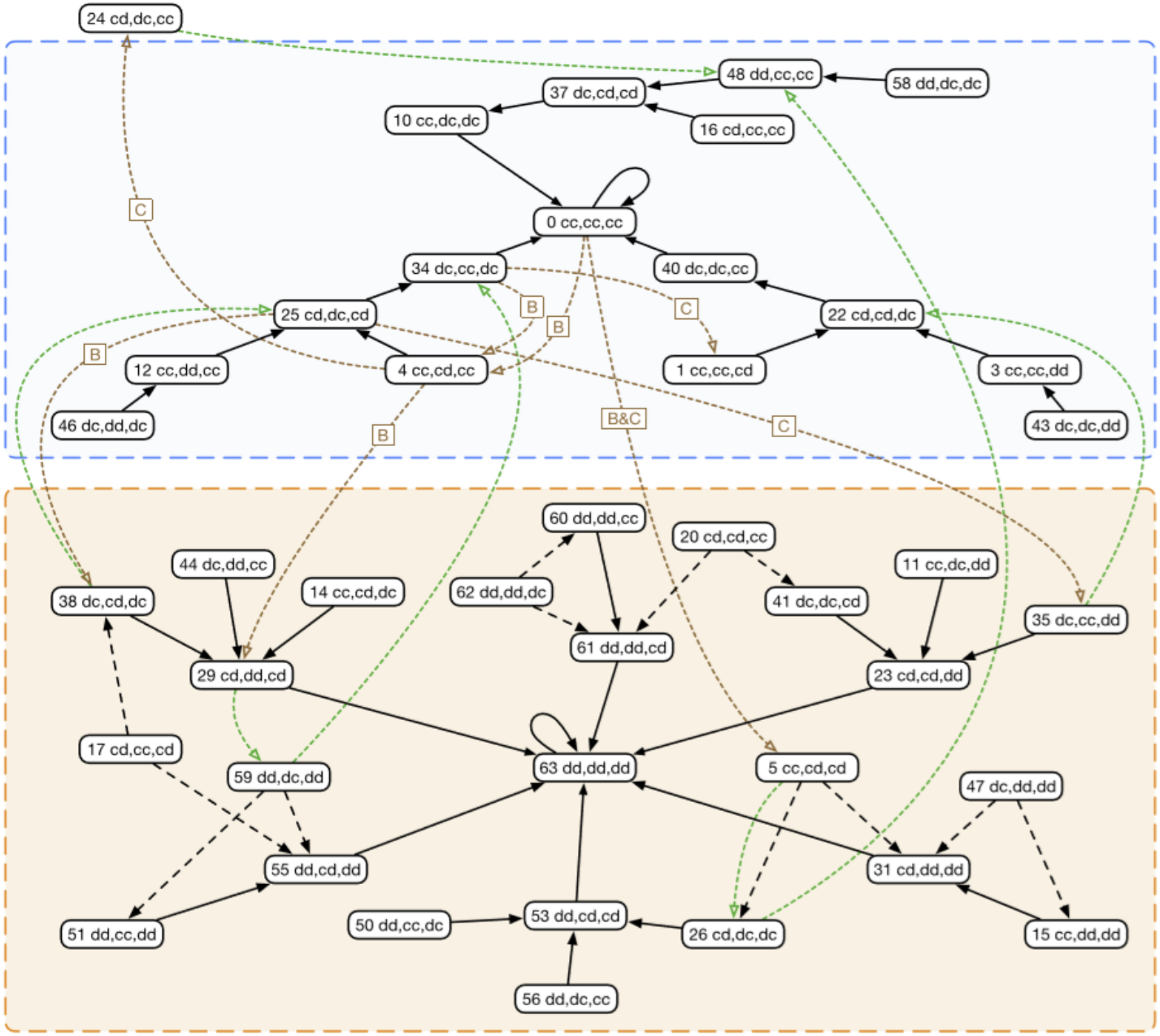
Murase and Baek started from memory two:

totally	1,099,511,627,776
⇒defensible	3,483,008
⇒partially efficient	544
⇒distinguishable	256

partially successful strategies

Y. Murase and S. K. Baek,
J. Theor. Biol. 449 p.94 (2018)

Path to cooperative Nash equilibrium with one and two-bit error
Highly nontrivial!



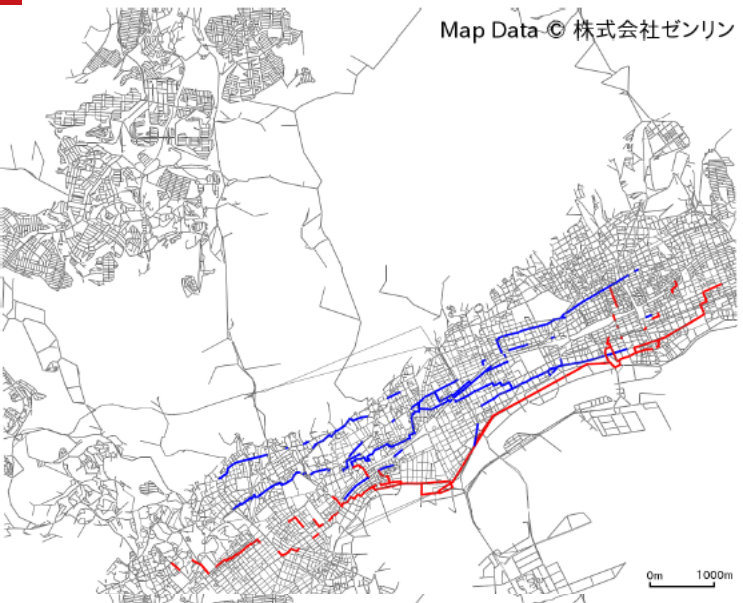
Tokyo

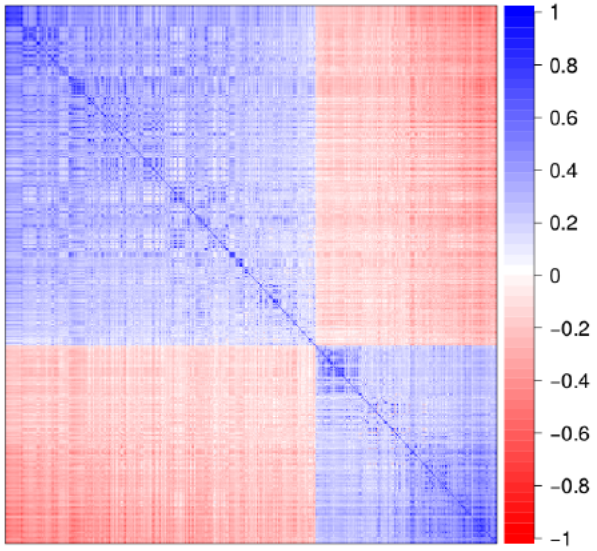
Kobe

Rome

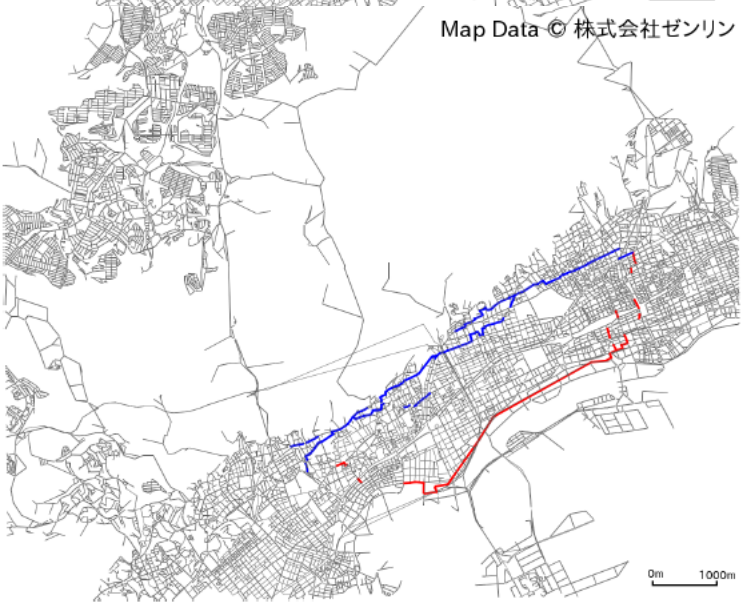
RIKEN R-CCS シミュレーションが未来をひらく

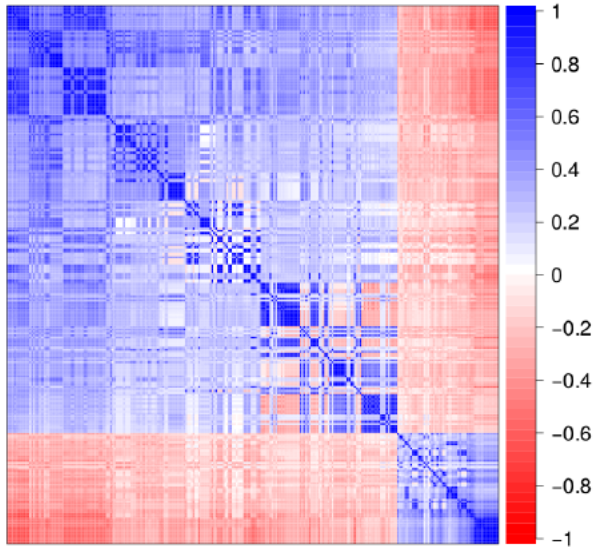
Two tops





Factor No.1: 10.3%

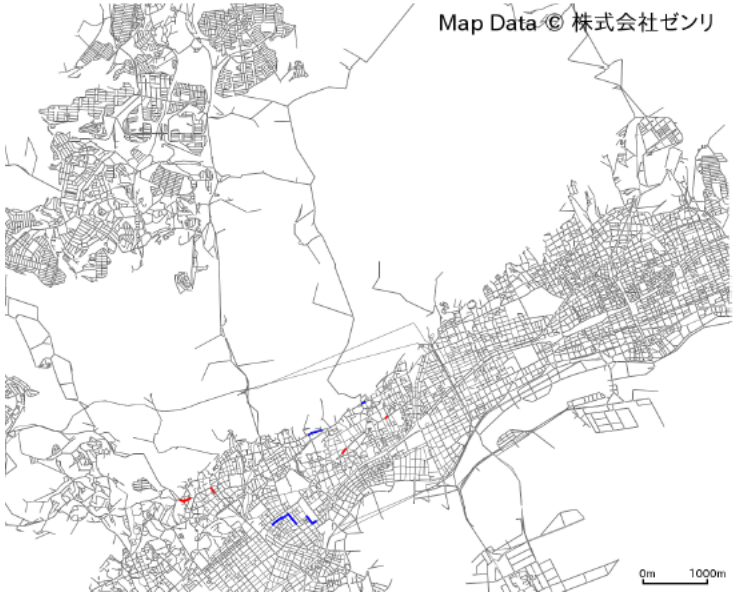


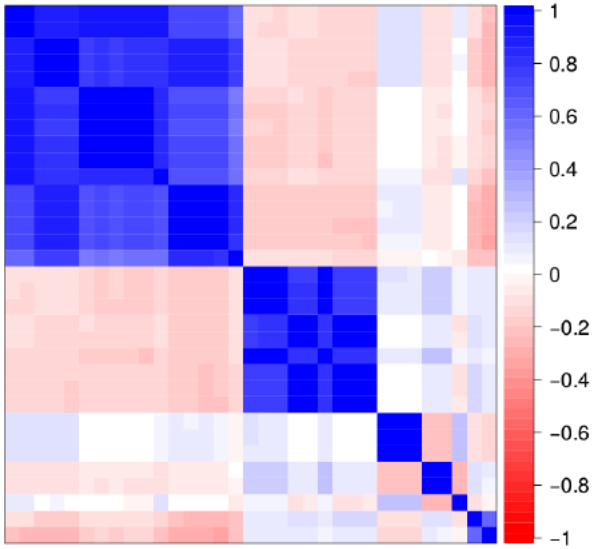


Factor No.2: 4.8%

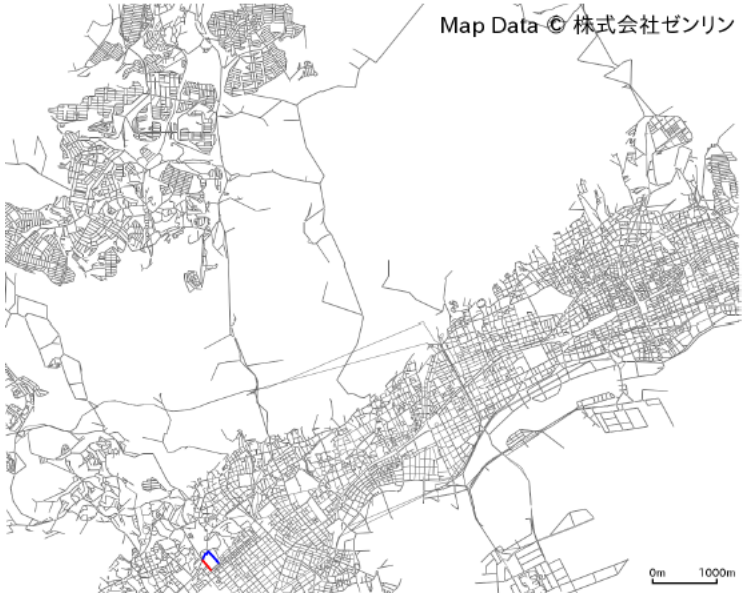
T. Uchitane and N. Ito, "Applying Factor Analysis to Describe Urban Scale Vehicfle Traffic Simulation Results," (in Japanese) J. Jpn. Measurement and Control Soc. vol.52 (2016) No.10 p.545-554.

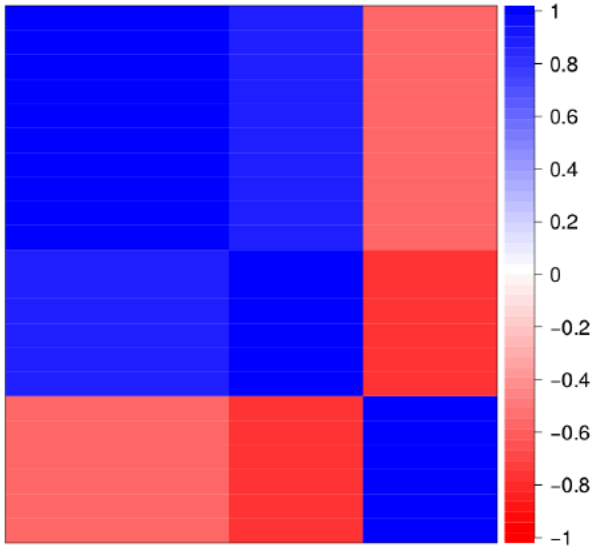
Two from minors





Factor No.19: 1.2%

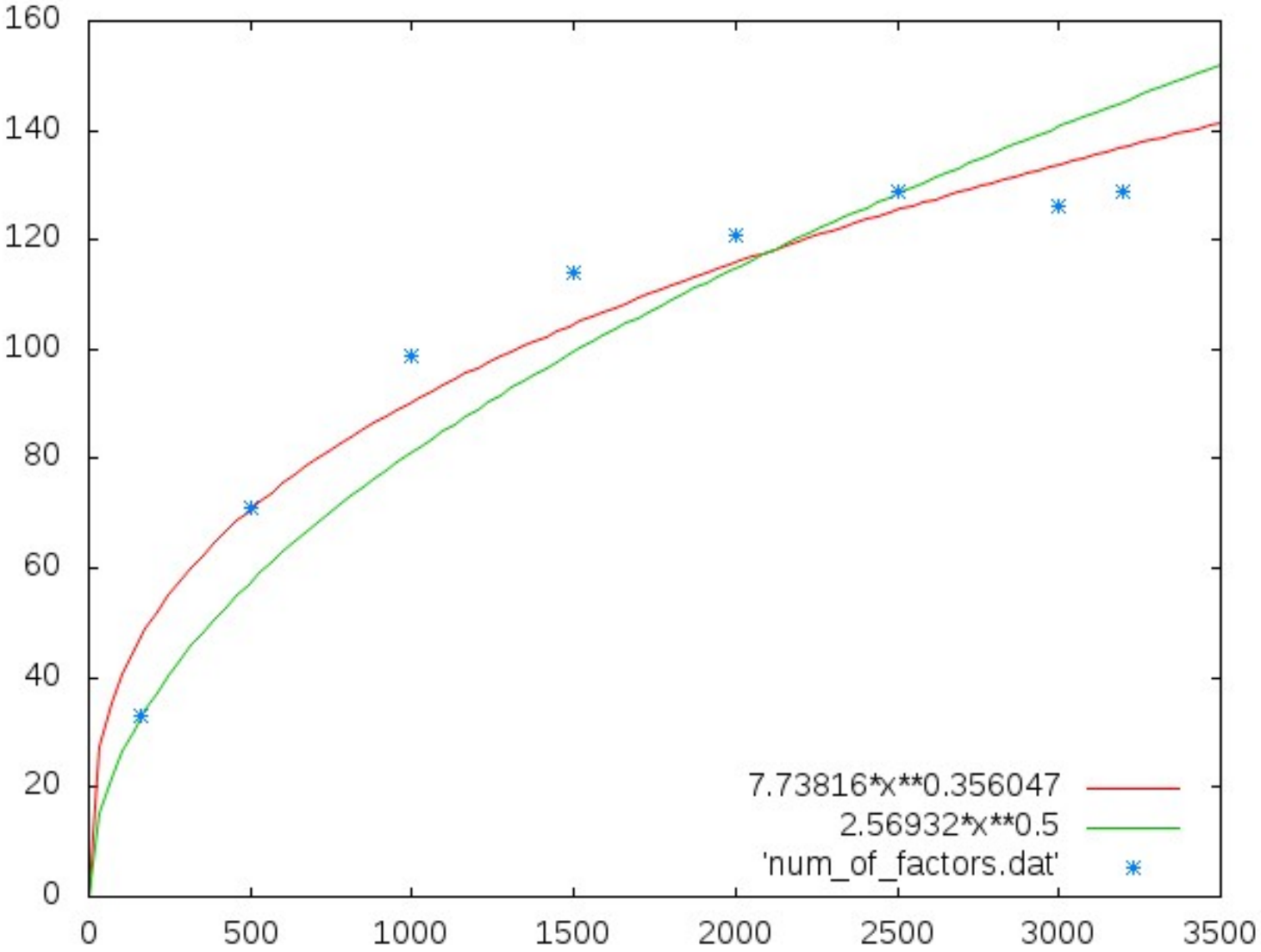


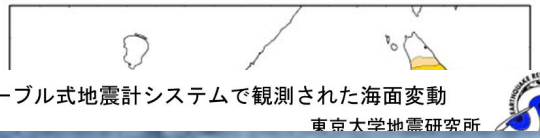


Factor No.13: 1.3%

T. Uchitane and N. Ito, "Applying Factor Analysis to Describe Urban Scale Vehicfle Traffic Simulation Results," (in Japanese) J. Jpn. Measurement and Control Soc. vol.52 (2016) No.10 p.545-554.

Number of traffic factors





釜石沖海底ケーブル式地震計システムで観測された海面変動

東京大学地震研究所

シミュレーションが
未来をひらく

130°

140°

Evacuation Simulation from Tsunami attack in Kamakura city in Japan

シミュレーションが未来をひらく

How long does the evacuation take?

図 4: 避難シミュレーションに適用する道路ネットワーク

3^7=2187 possibilities

Initial distribution: random

simulation with an pedestrian simulator, CrowdWalk

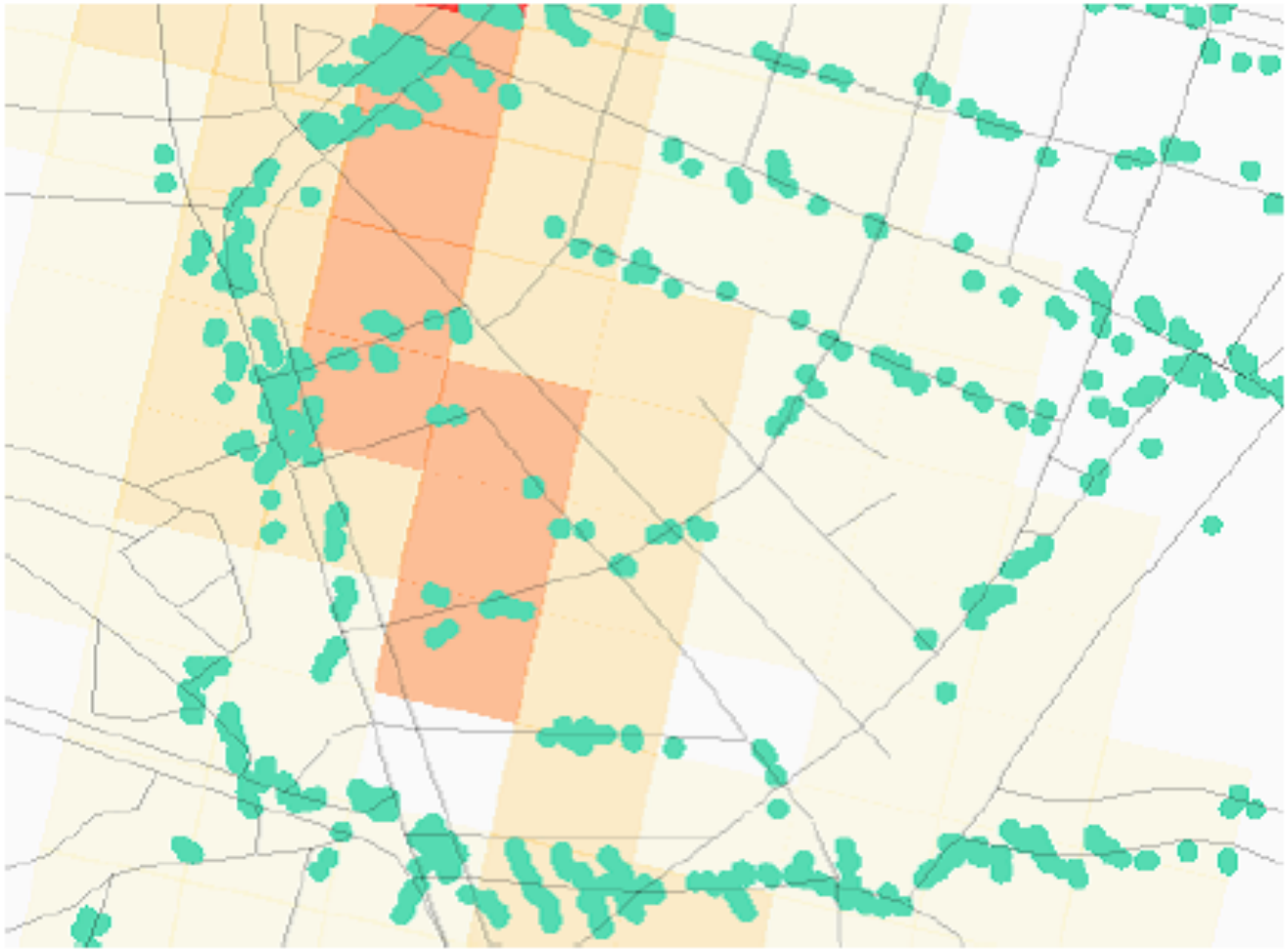
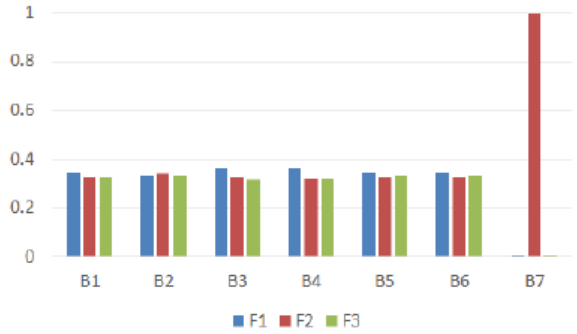
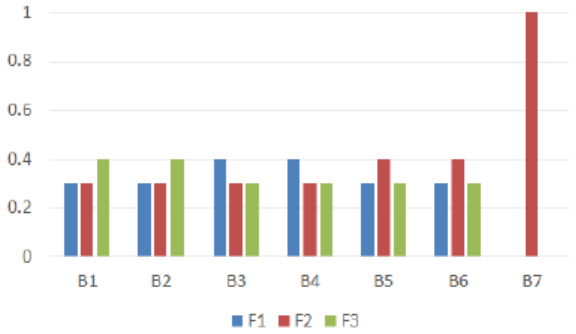


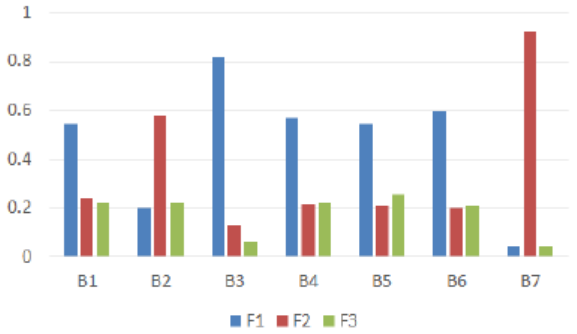
図 3: CrowdWalk によるシミュレーションの例



(a) Case1: ワースト 1,500 サンプル

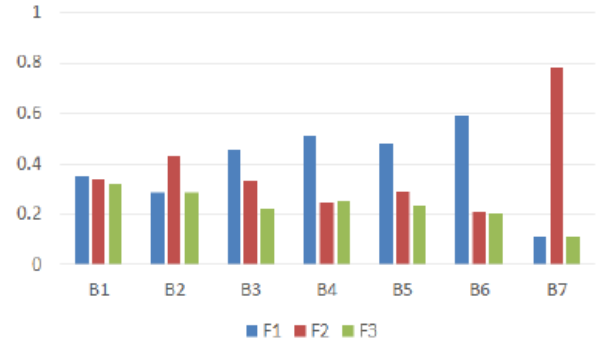


(b) Case2: ワースト 10 サンプル

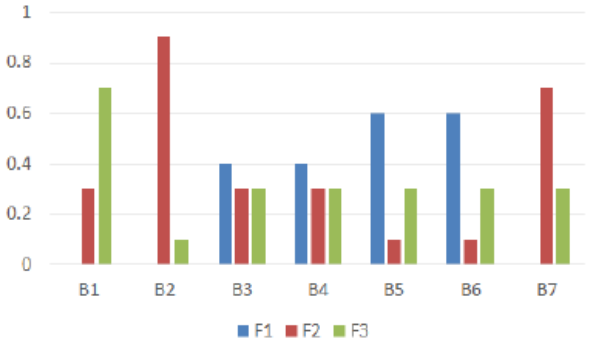


(c) Case1: ワースト 150 サンプル

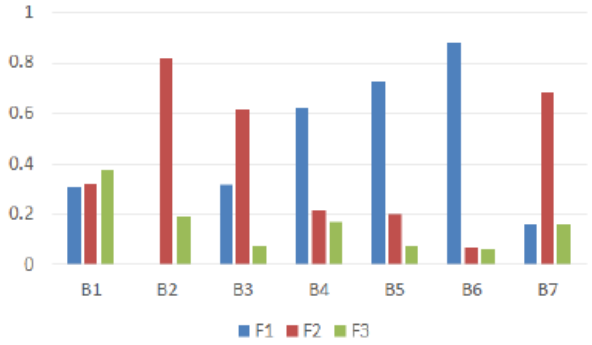
図 9: $pop = 2000$ における最も避難完了時間が長い入力パラメータの頻度



(a) Case1: ワースト 1,500 サンプル

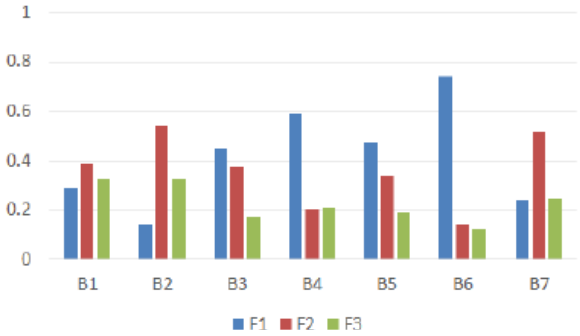


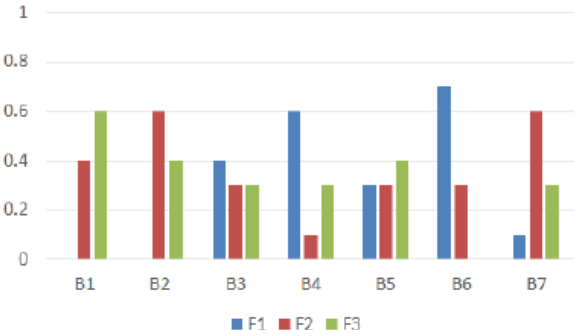
(b) Case2: ワースト 10 サンプル

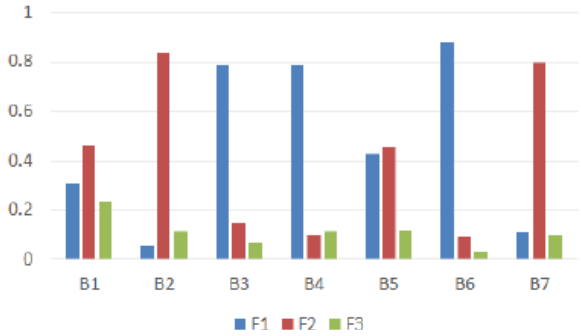


(c) Case1: ワースト 150 サンプル

図 10: $pop = 3000$ における最も避難完了時間が長い入力パラメータの頻度







H. Matsushima, T. Uchitane, J. Tsuji, T. Yamashita, N. Ito and I. Noda, "Applying Design of Experiment based Significant Parameter Search and Reducting Number of Experiment to Analysis of Evacuation Simulation," (in Japanese) Transactions of the Japanese Society for Artificial Intelligence vol.31 (2016) No.6 p.AG-E 1-9

Evacuation from a Tsunami attack in Nishi-Yodogawa ward in Osaka

Scale

City map: 2933 nodes, 8924 links

Evacuees: 49276

Evacuation plan

from 73 area

in each area, i, evacuees are divided into two groups with population ratio $x_i : 1\text{-}x_i$

via one of 533 check-points

to one of 86 safe places

$\Rightarrow$ search optimal plan in possible

$533^{146} \cdot 86^{146} \cdot \Pi(\text{number of } x_i \text{ options}) \approx 3.5 \times 10^{680} \cdot \Pi(\text{number of } x_i \text{ options})$ plans

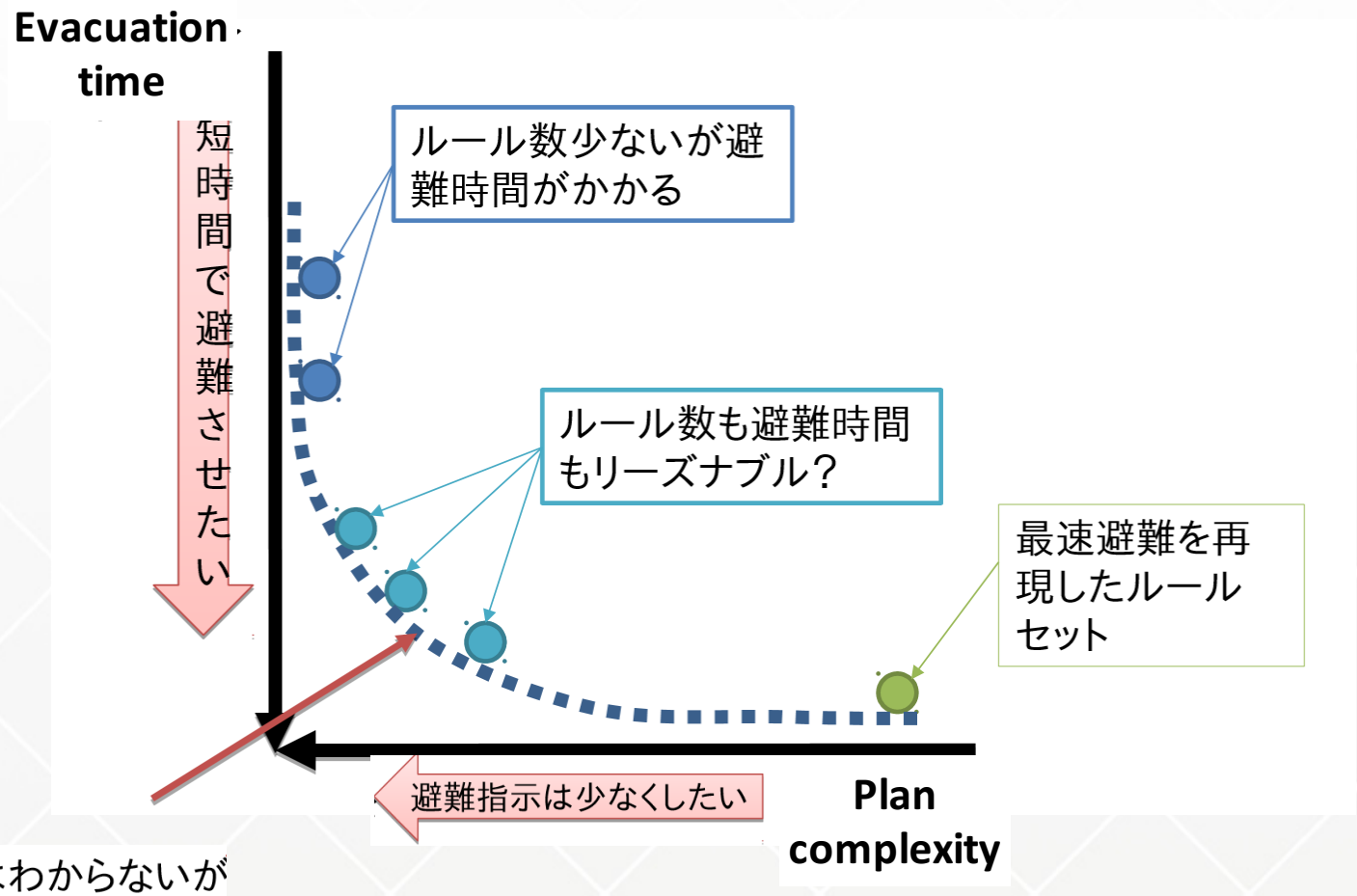
Evaluation with evacuation time vs complexity of evacuation plan

complexity: $S = -\sum x_i \ln x_i$

Evacuation time vs plan complexity

シミュレーションが未来をひらく

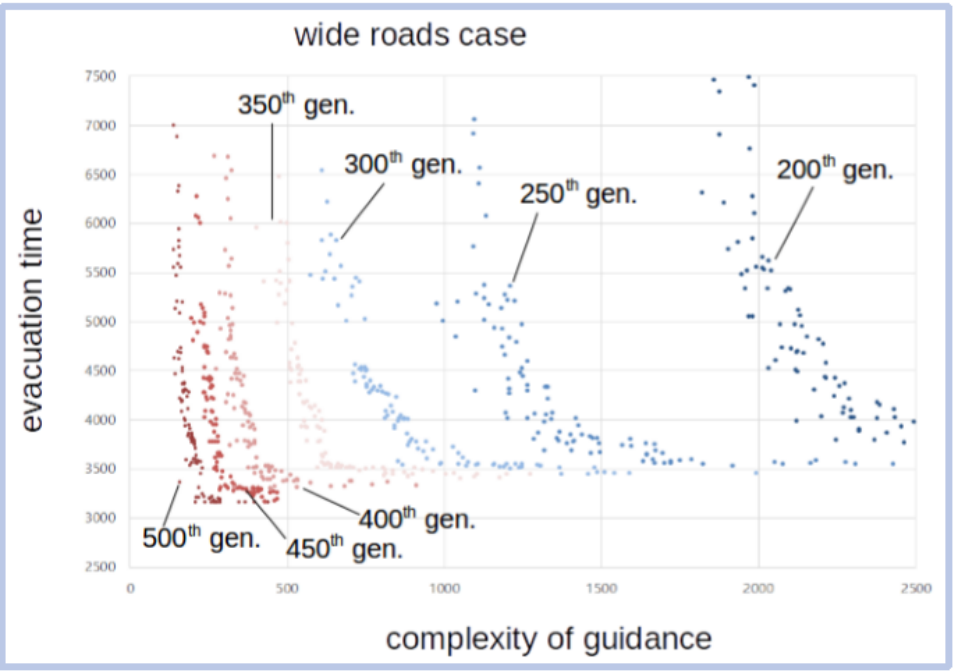
- Paleto optimal Trade-off line

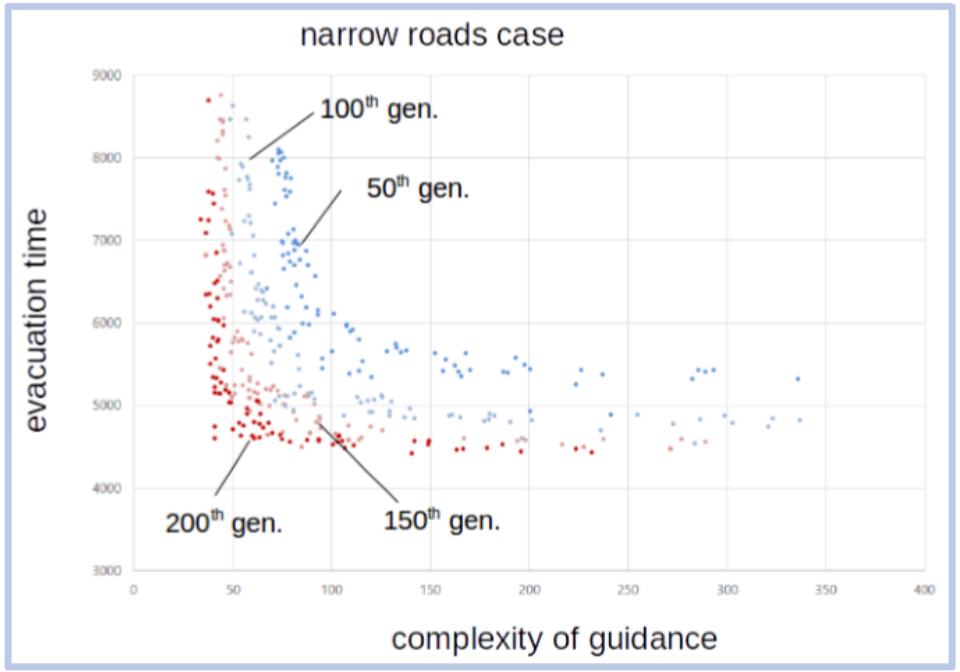


パレート面の形はわからないが最適化手法の適用で把握したい

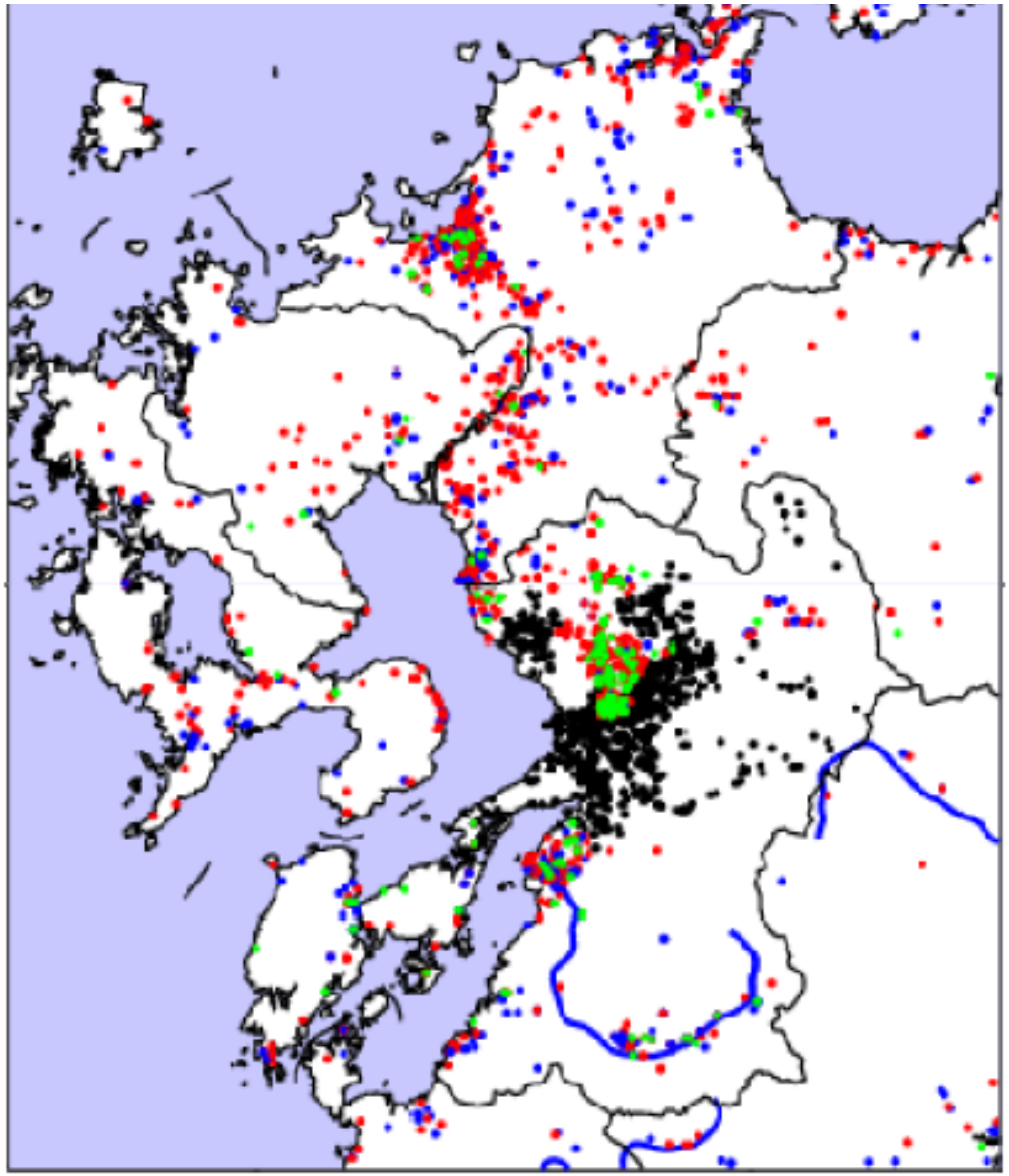
Result

- **Nishiyodogawa ward in Osaka city**
  - **Wide roads case : use both pedestrian and car zone**
  - **Narrow roads case : use pedestrian zone only**





GDP damage from an eqarhquake in Kumamoto on Apr. 16th, 2018
Estimated to be 0.7 trillion JPY/month (8.1 / year)
by Misako Takayasu(Tokyo Inst. Tech., 2016 April 18)



震度6以上

益城町宮園
玉名市天水町
西原村小森
宇城市松橋町
宇城市不知火町
宇城市小川町
宇城市豊野町
熊本東区佐土原
熊本西区春日
熊本南区城南町
熊本南区富合町
宇城市豊野町
氷川町島地

−0.42兆円/月

避難勧告

宇土市
阿蘇郡南阿蘇村
菊池市
上益城郡
下益城郡
菊池郡

−0.23兆円/月

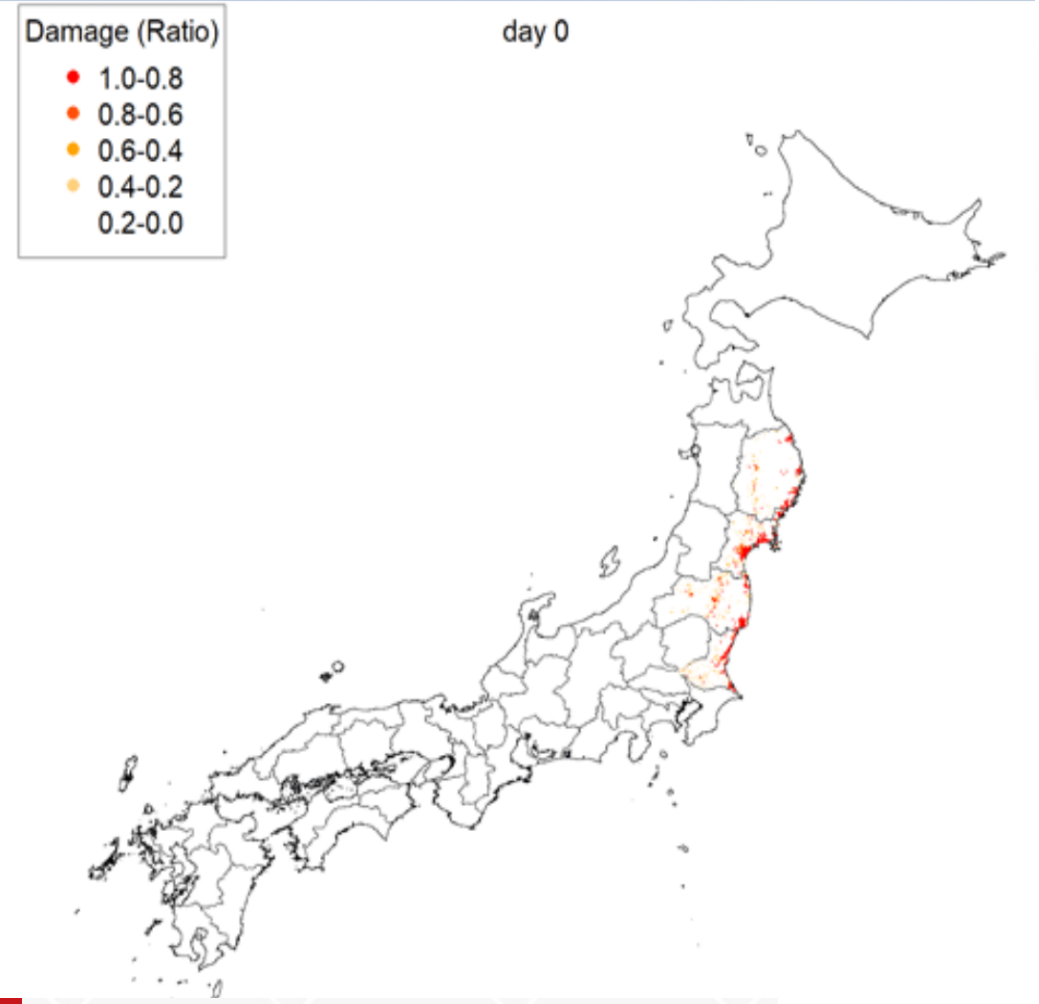
黒:直接被災
緑:孤立
青:5%以上売上増
赤:5%以下売上減

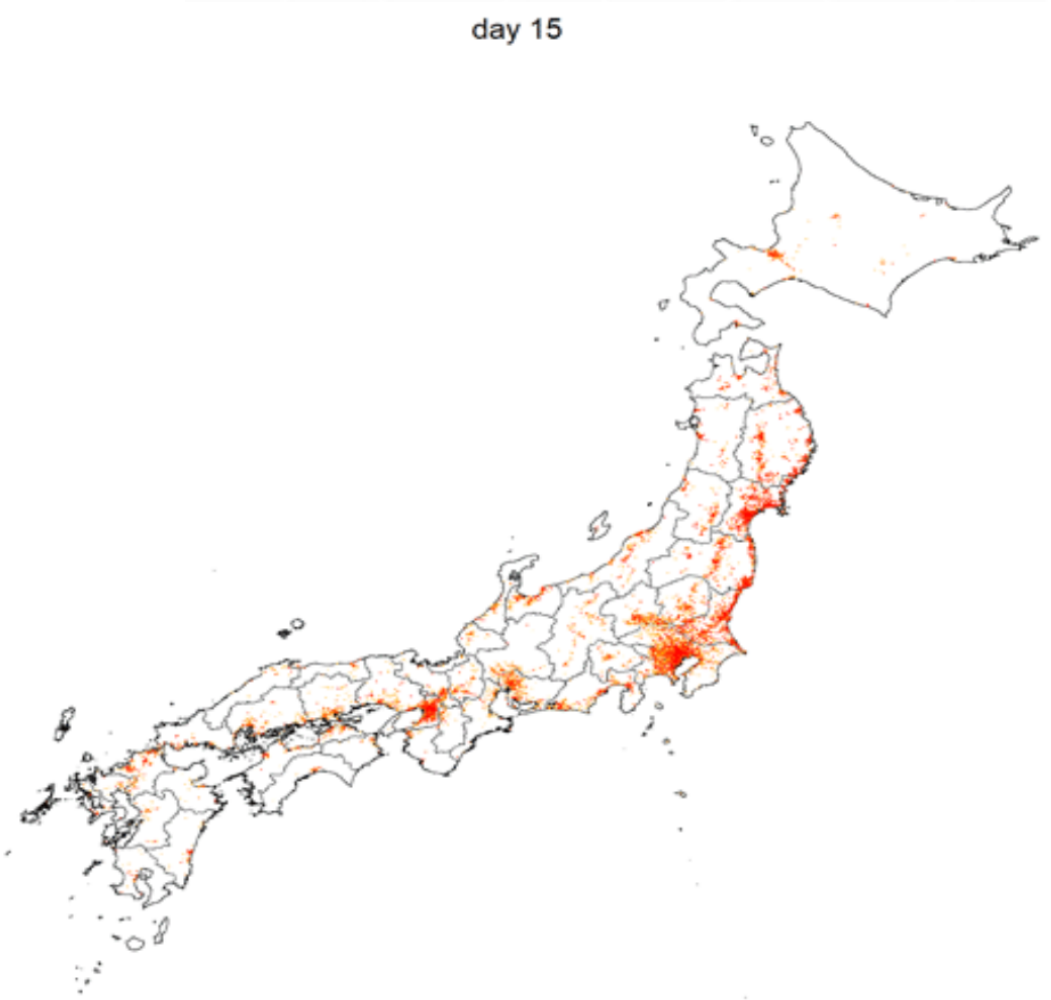
約0.7兆円/月の被災額

e.g 利根川氾濫:1.6兆円/月
東北津波 : 0.5兆円/月

GDP damage dynamics estimation after an earthquake in East Japan on Mar. 11th, 2011

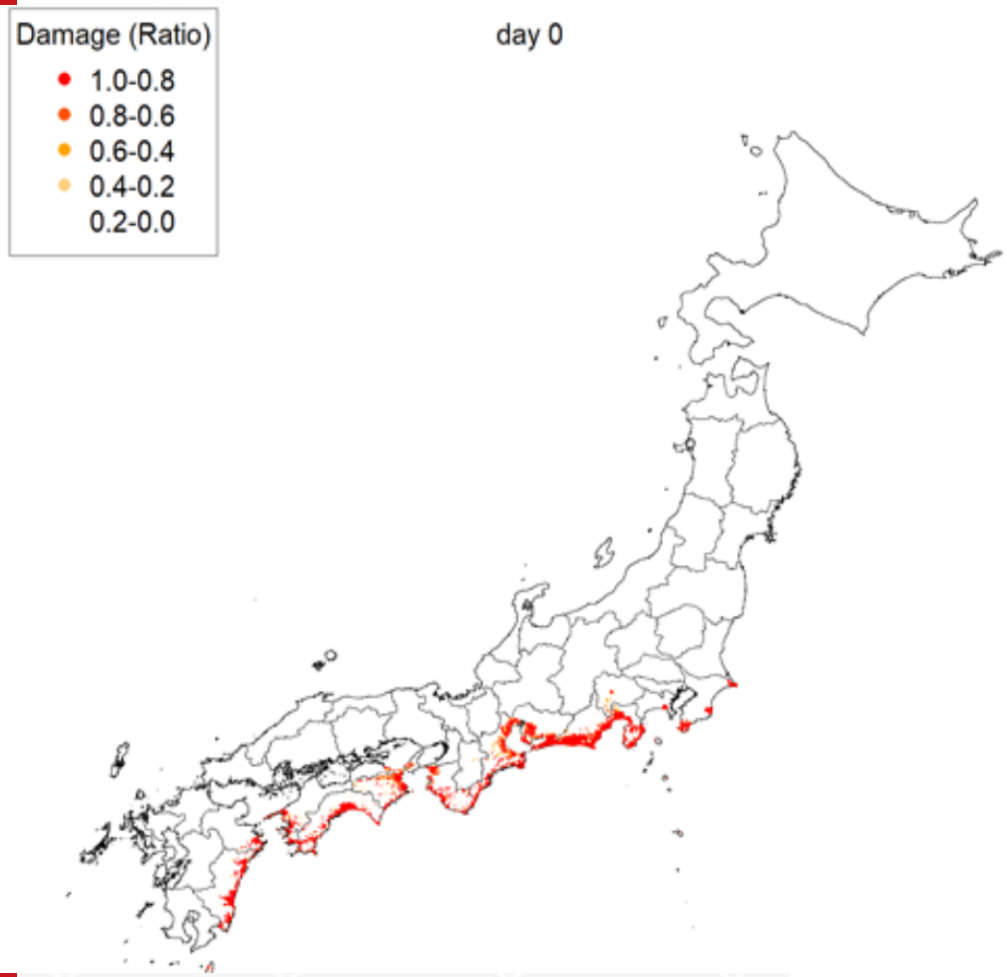
by H. Inoue and Y. Fujiwara
(Hyoto Pref. Univ.)

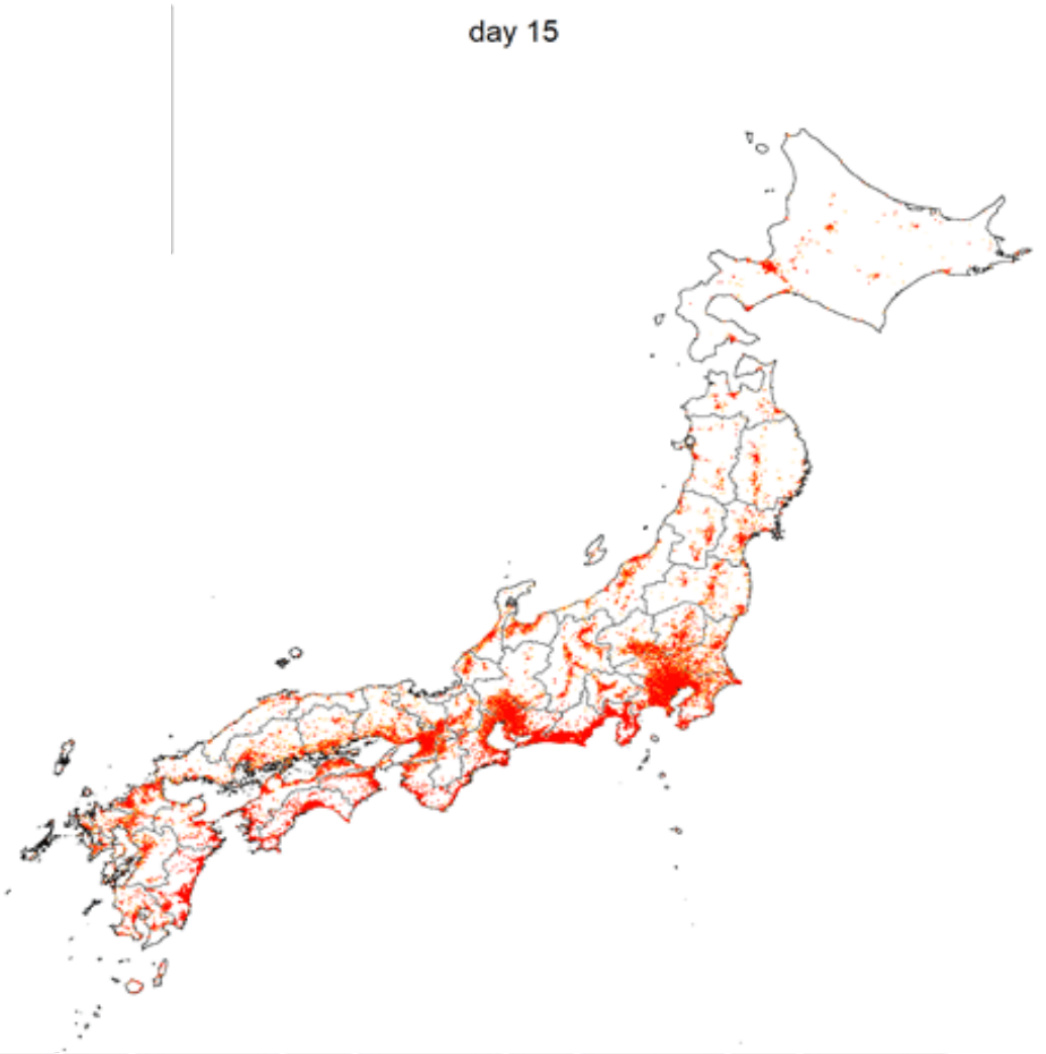




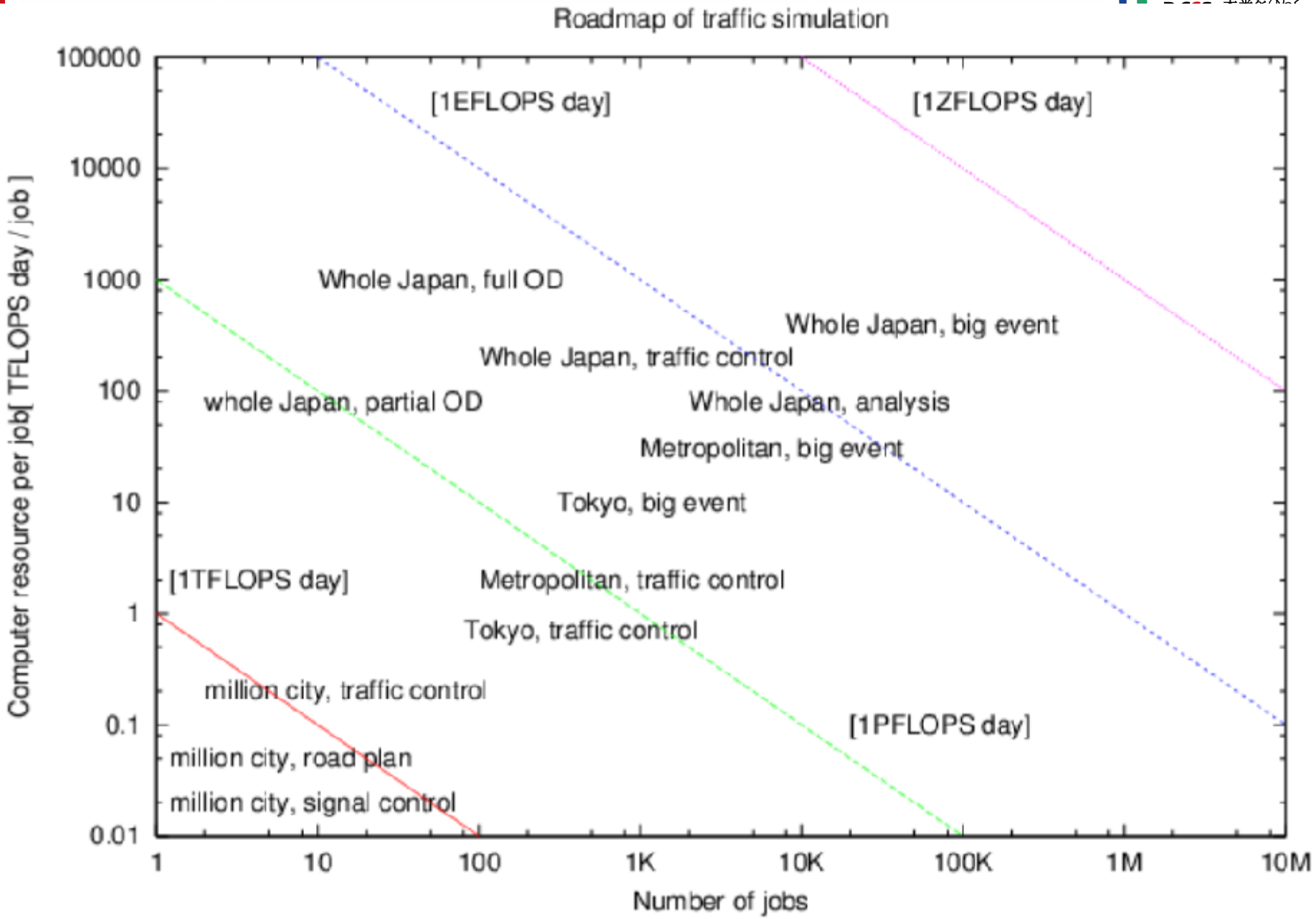
GDP damage dynamics estimation after a foreseen earthquake in South Japan

by H. Inoue and Y. Fujiwara
(Hyoto Pref. Univ.)



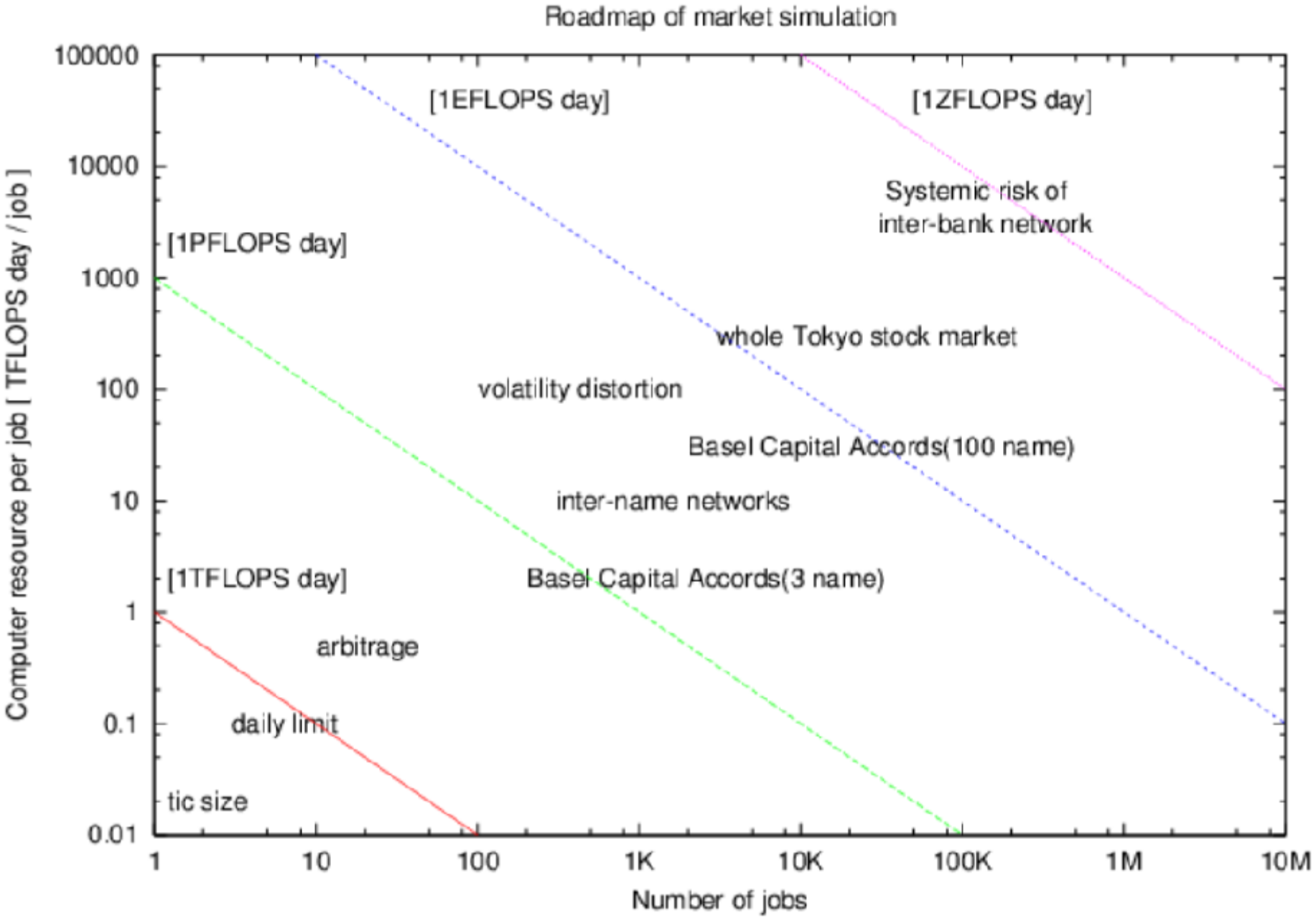


Perspectives of social simulations with HPC



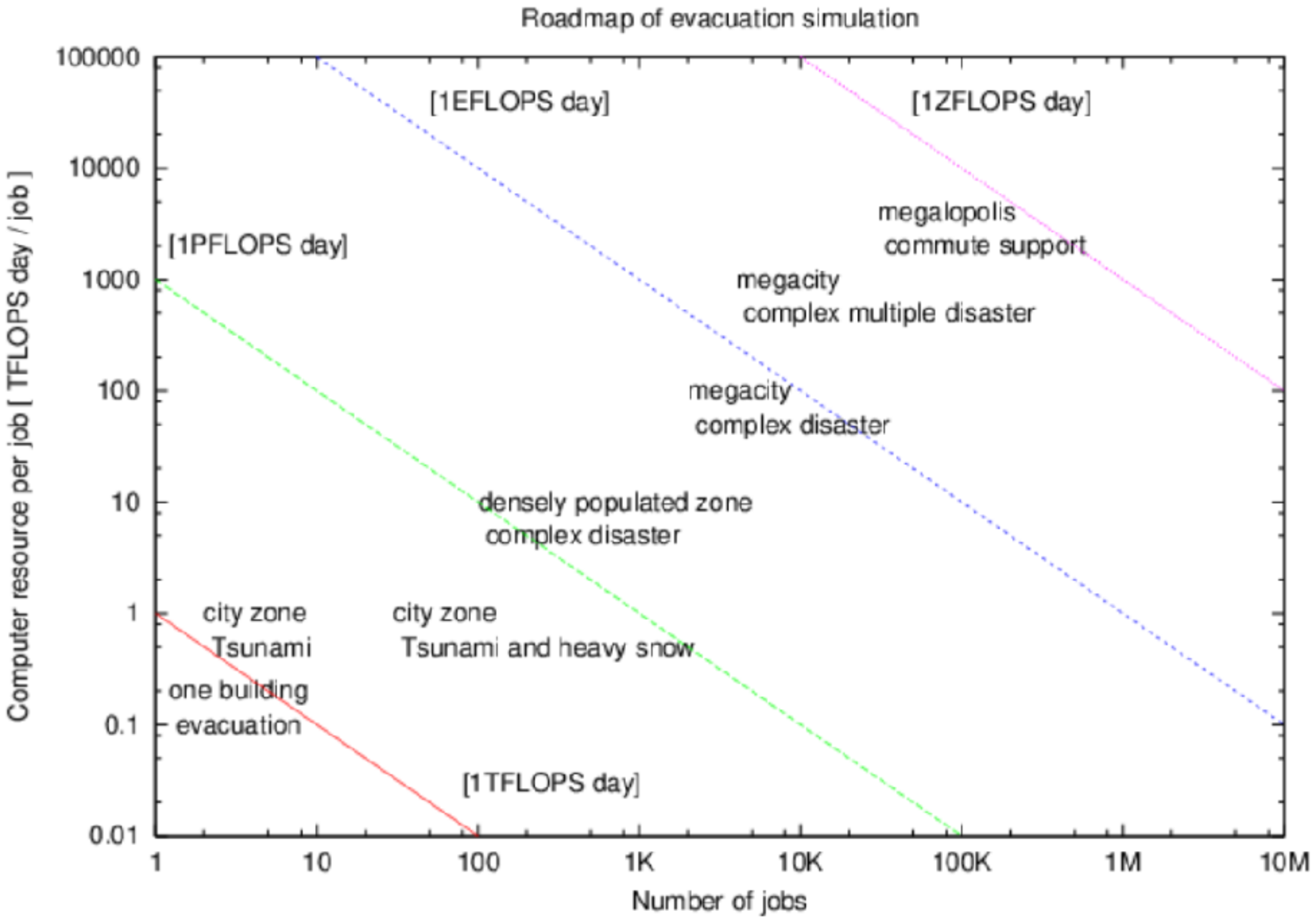
T. Noda, N. Ito, K. Izumi, T. Yamashita, H. Mizuta, T. Kamada, T. Murase, S. Yoshimura and H. Hatton, in preparation.

Perspectives of social simulations with HPC



I. Noda, N. Ito, K. Izumi, T. Yamashita, H. Mizuta, T. Kamada, Y. Murase, S. Yoshihama and H. Hattori, in preparation.

Perspectives of social simulations with HPC



I. Noda, N. Ito, K. Izumi, T. Yamashita, H. Mizuta, T. Kamada, Y. Murase, S. Yoshihama and H. Hattori, in preparation.

Reseach group and financial support

シミュレーションが未来をひらく

JST CREST Project "CASSIA" 2012 October ～2017 March

and

Multiscale Social and Economics SIMlation Project for the Post K computer and beyond (PostK-MultiSESIM)
2016 August～2020 March　　MEXT Japan

Group A: Macroeconomics

Hyogo Pref. Univ.
Y. Fujiwara
H. Inoue

with
F. Shoji, RIKEN CCS
Y. Ikeda, Kyoto Univ.
H. Iyetomi, Niigata Univ.
W. Soma, Nihon Univ.
H. Yoshikawa, Rissyo Univ.
M. Arata, RIETI

cooperation with
CMD laboratory
Marche State Univ.
Palermo Univ.
Boston Univ.
Kiel Univ.

Macro GDP simulator
Economic crysis analyzer

Group B: Local economics

Tokyo Insti. Tech.
M. Takayasu

cooperation with
Columbia Univ.
Bar Ilan Univ.
Imperial College London
Teikoku Data Bank

Economic activity simulator

Group C: Finance

Univ. Tokyo
K. Izumi

with
T. Kamada, Kobe Univ.

cooperation with
JPX

Financial market simulator

Director
RIKEN CCS
Nobuyasu Ito

Group D: Traffic and Crowd

AIST
I. Noda

with
T. Asano, Shonan Inst. Tech.
H. Hattori, Ritsumeikan Univ.
H. Fujii, Univ. Tokyo

Cooporation with
Chiba Univ.　Kyoto City
Okayama Pref.　NEC

Car-traffic simulator
Disaster-evacuation simulator

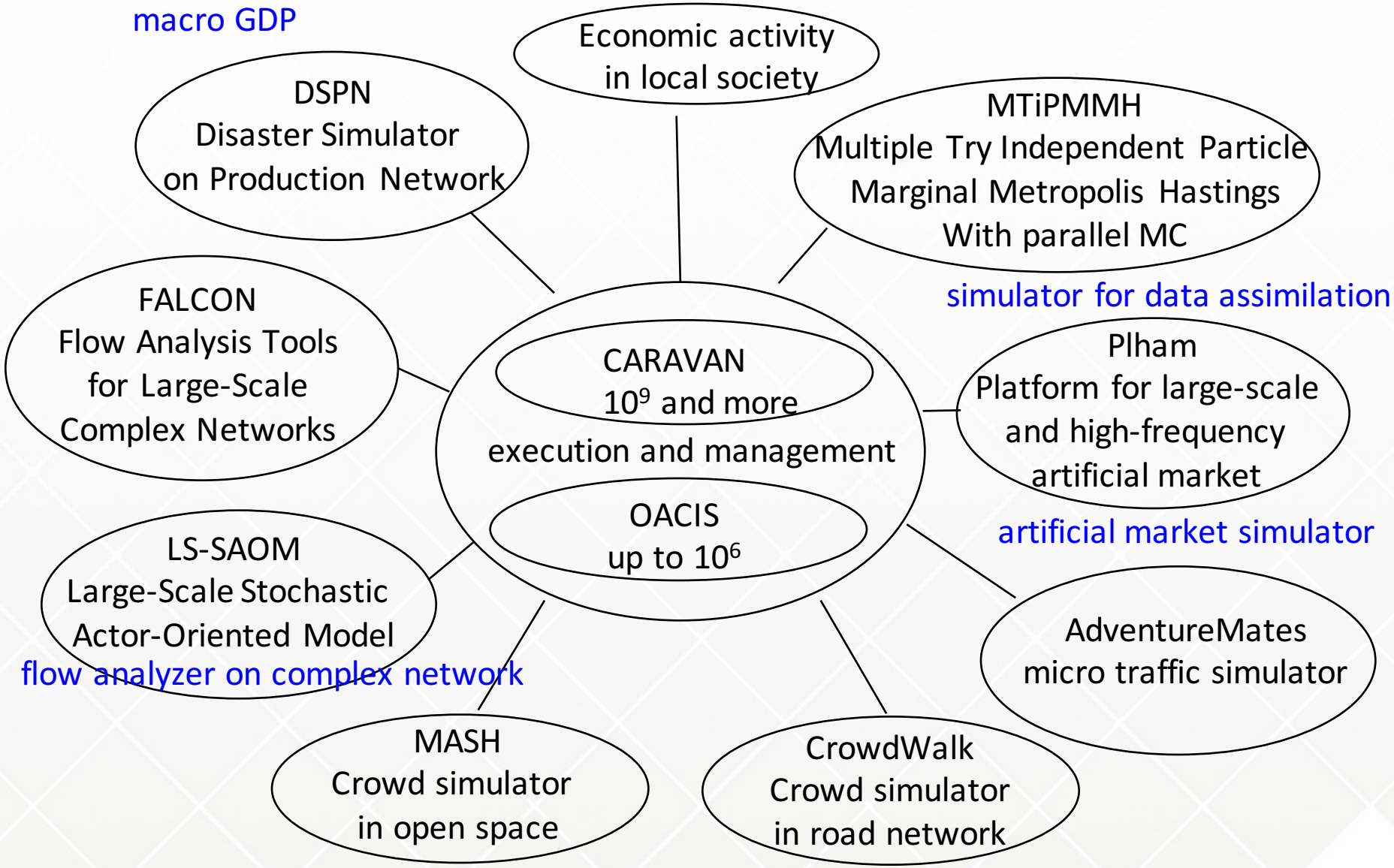
Group E: Model evaluation

Kobe Univ.
T. Kamihigashi
M. Yokokawa

with
T. Ikegami, Univ. Tokyo
N. Ito, Riken CCS

Model evaluation application
Job-execution and management application

Applications for social and economics simulations for Post-K computer
(to be onstage in March 2020)



PostK-MultiSESIM project