Real Time Prediction of People Movement in Disaster Situations

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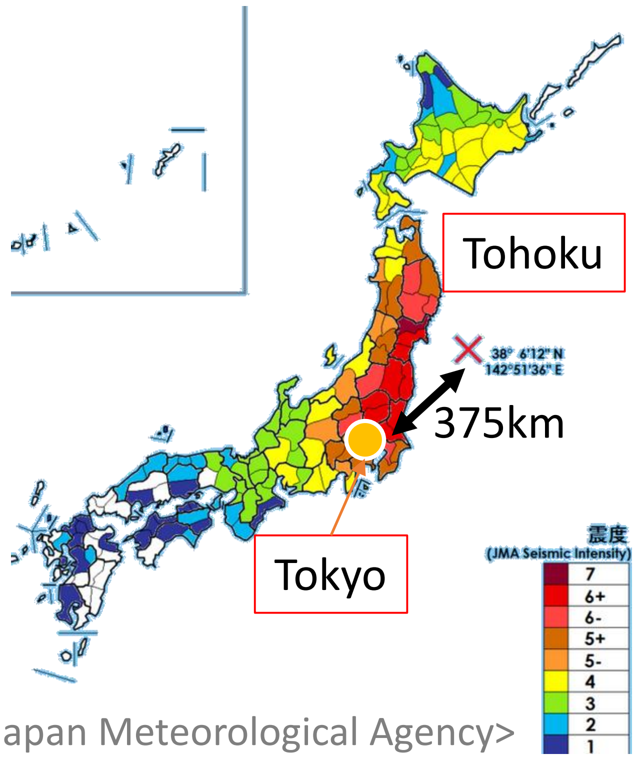
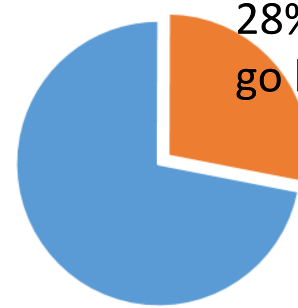
Great East Japan Earthquake (March 11th 2011)



<Japan Meteorological Agency>

In Tokyo, many people (mainly workers) couldn't go home on that day, because of the collapse of public transportation.

Shibuya Bus Terminal



= 5.15 million people

<Cabinet Office Documents>

Confusion due to Extreme Congestion

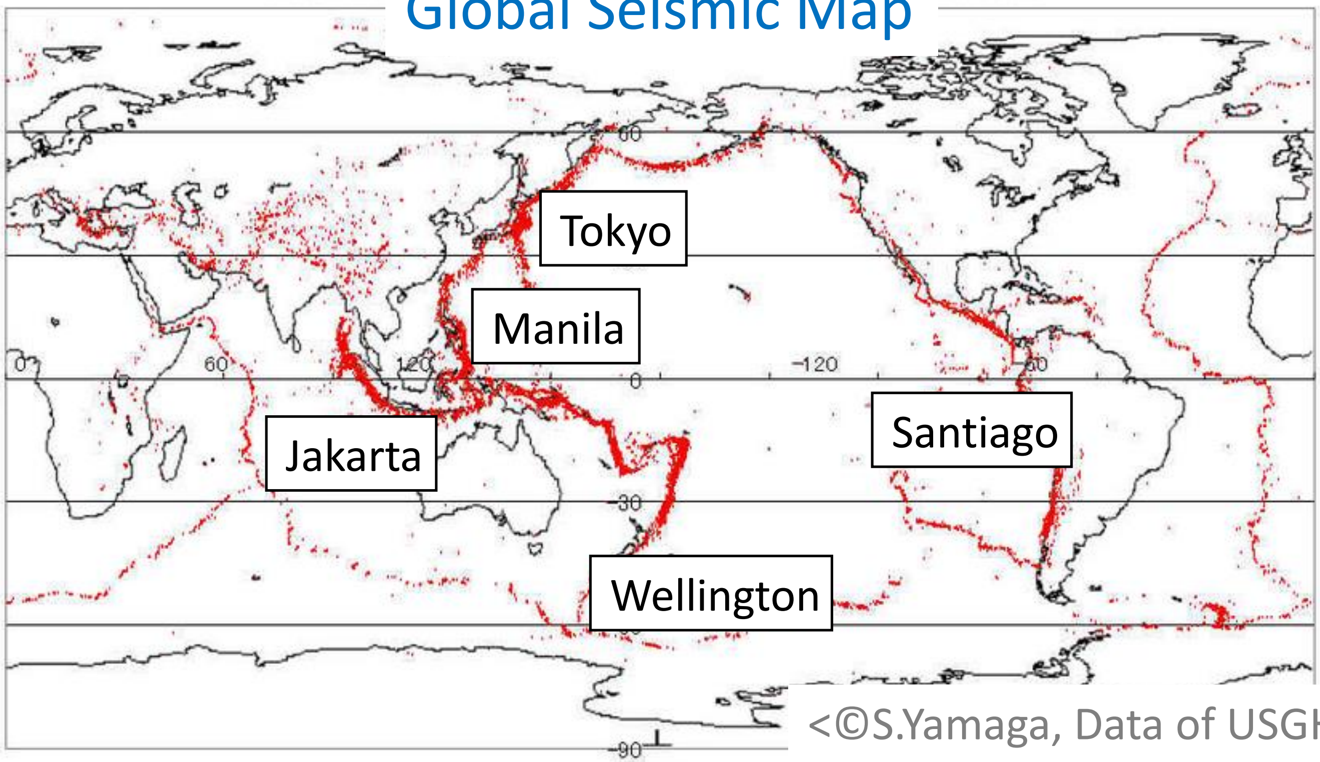
Secondary Damage

Late Rescue

Insufficient Distribution of Supplies

Many Disaster-Prone Cities Worldwide

Global Seismic Map



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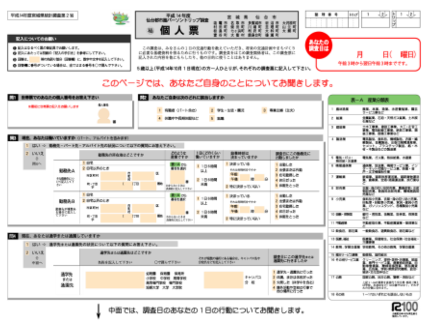
→ A Serious Issue for Many Countries (Nepal 2015, Japan/New Zealand 2011...)

By predicting Post-Disaster People Movement in Real-Time,
we can alleviate the damage to society and people
→ A valid, data-driven information for decision making

Prediction of Daily People Flow/Distribution

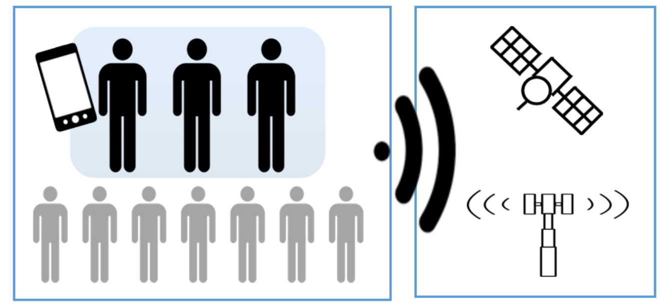
- Sekimoto *et al.*(2011)



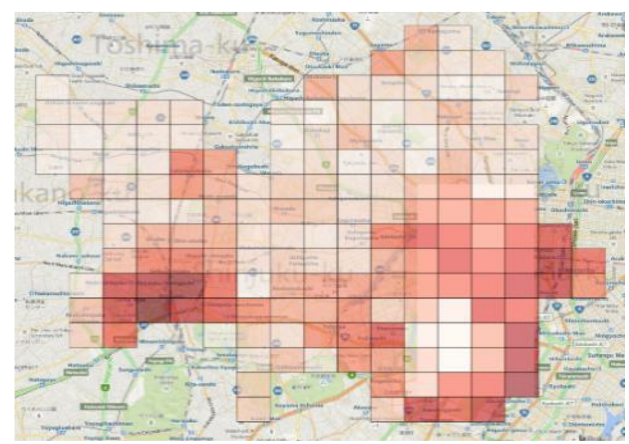
Questionnaire of Daily Activities of 0.8 million samples in Tokyo (2%)

Daily Individual People Flow Data

- Zenrin Data Com (Data company)



GPS Data of 0.5% samples who have agreed to provide their location data



Real-Time Population Density Data

People Movement Prediction in Disaster Situations

Multi Agent Simulation using a Disaster Behavioral Model

Osaragi (2008), Usami(2007)

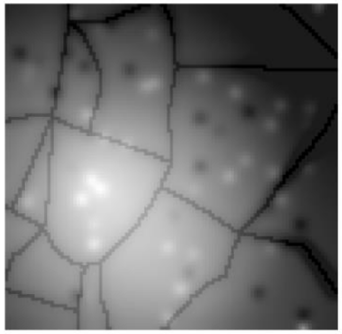
Questionnaire to victims

Parameters of behavior

Multi agent simulation

Assimilating Observed Data for Improving Prediction

Madey (2006), Chen *et al*. (2011)



Real-time Prediction of People Flow

Potential field from real-time data

However, past researches

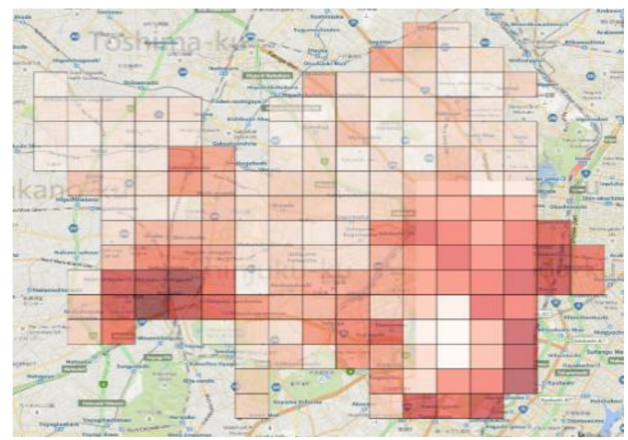
- Cannot be used in real-time prediction which is most needed for disaster reaction.
- Do not have a 'white-box' model which can explain "for what reason" the people moved that way, which is important in decision making.

Problem Definition

Can we predict the population distribution of few hours ahead in a Metropolitan scale in a Disaster Situation?

Combining …

Daily Individual People Flow Data

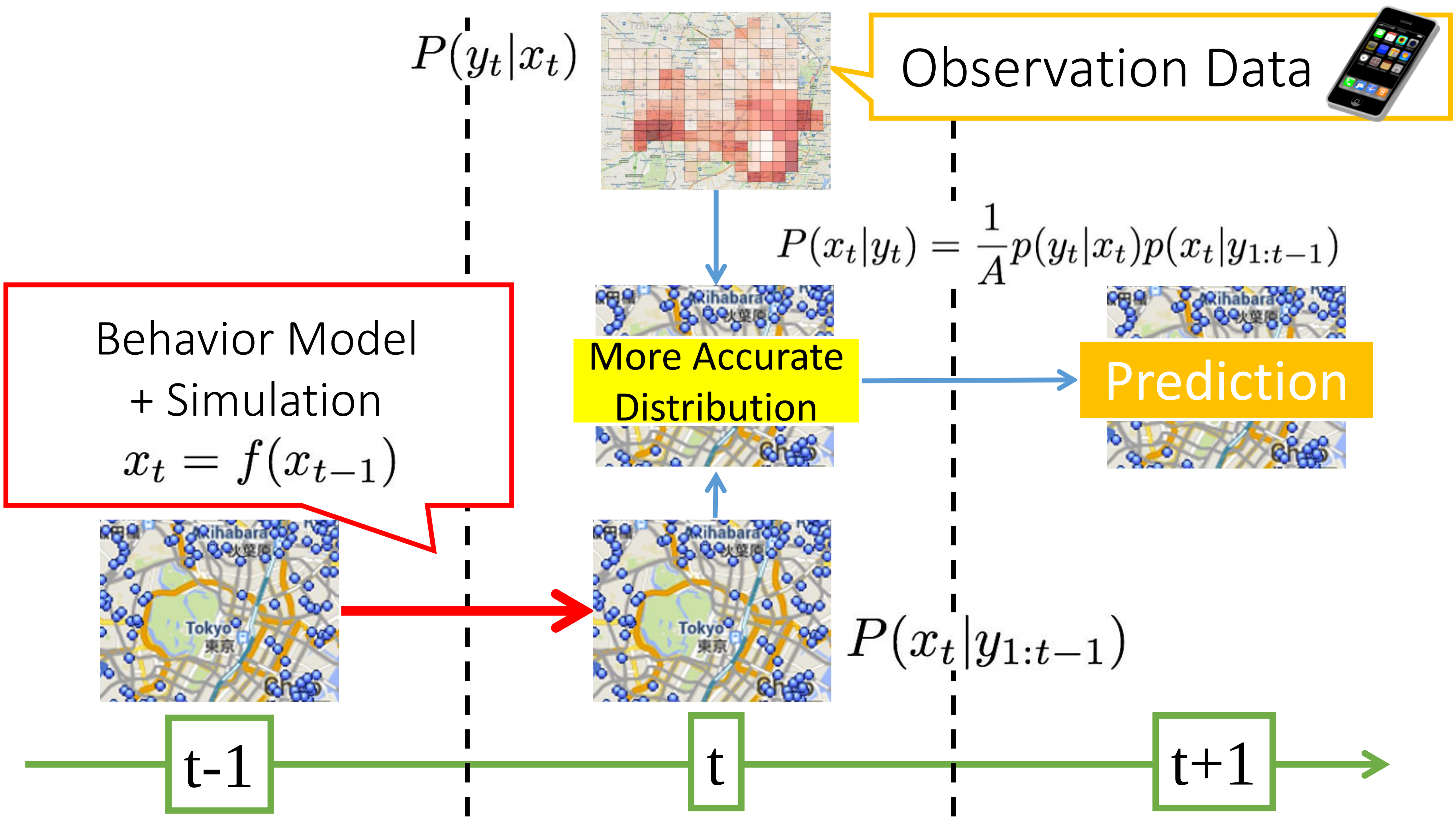


Real-Time Population Density Data
In time of Disaster

Real Time Prediction of People Movement in a Disaster Situation

Data Assimilation

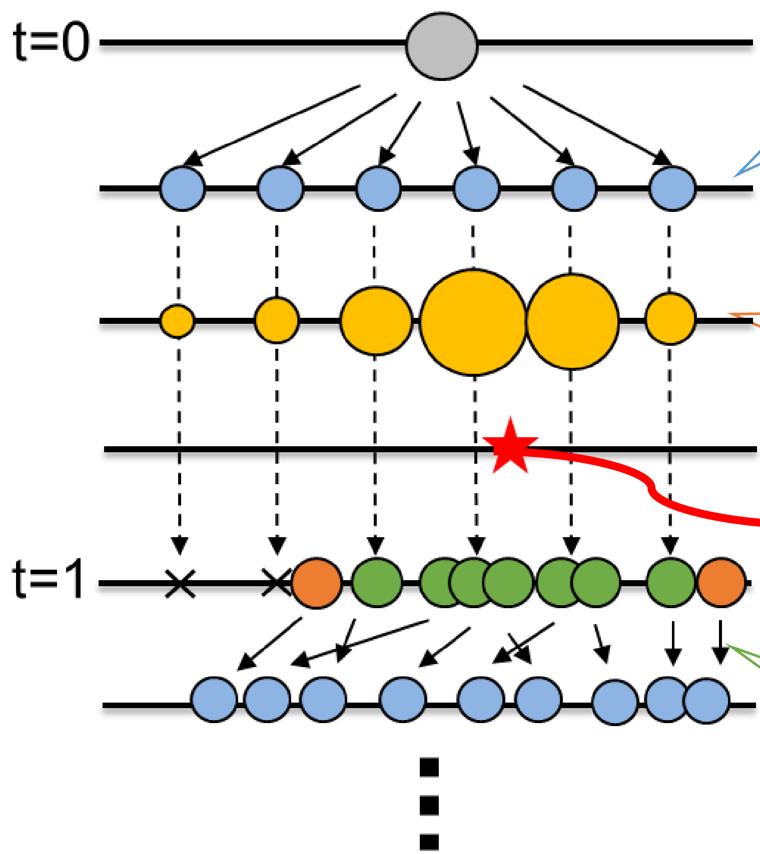
Combines Simulation and Observation Data for accurate prediction



Advanced Particle Filter Method

"A Particle"= A Scenario of People Distribution

Components: {Disaster Behavior Model Parameters, Location info of all agents}



Produce many particles using BM + Sim (=scenario candidates)

Evaluate the likelihood of all particles
And calculate most likely particle

Calculate Optimum Parameters

Resample particles for next time step

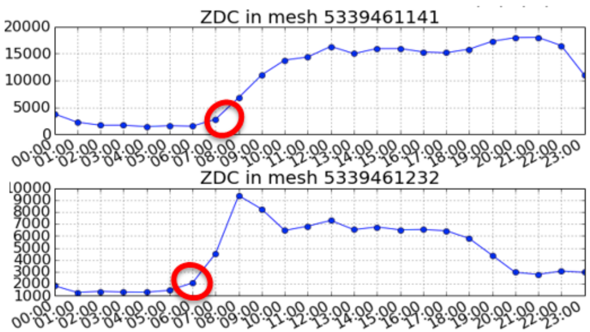
Why Advanced PF is Needed

A Problem with People Flow Prediction

A RAPID Change of Flow

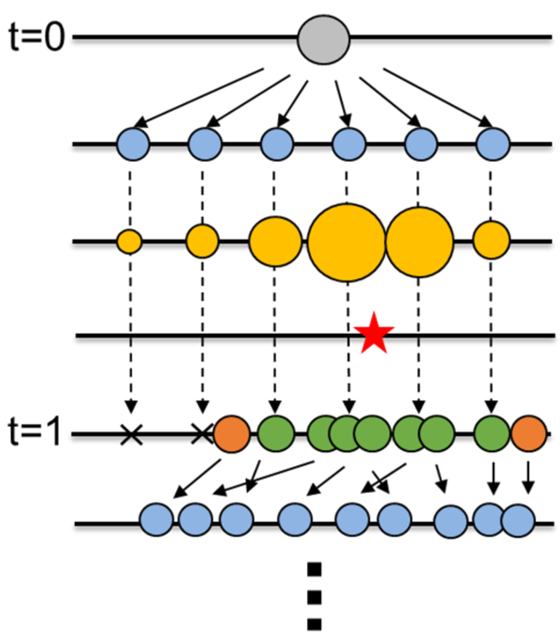
Tokyo Station

Kayaba Station



Probability that PF would not be able to adapt to RAPID Change

→ Needs Supportive Particles



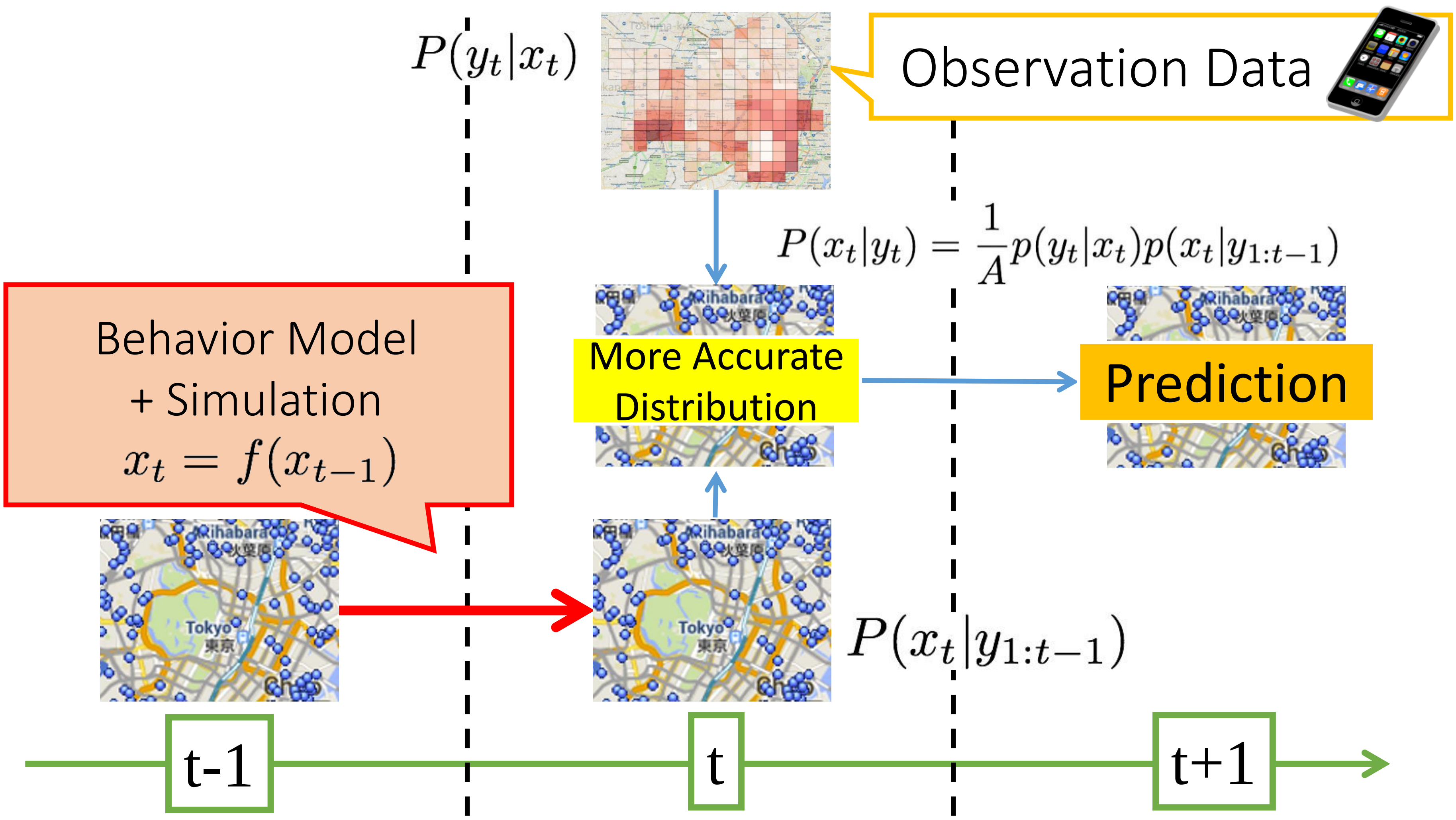
When Resampling the Particles for Next Time Step…

- Put Supportive Particles
- Add White Noise to All Particles

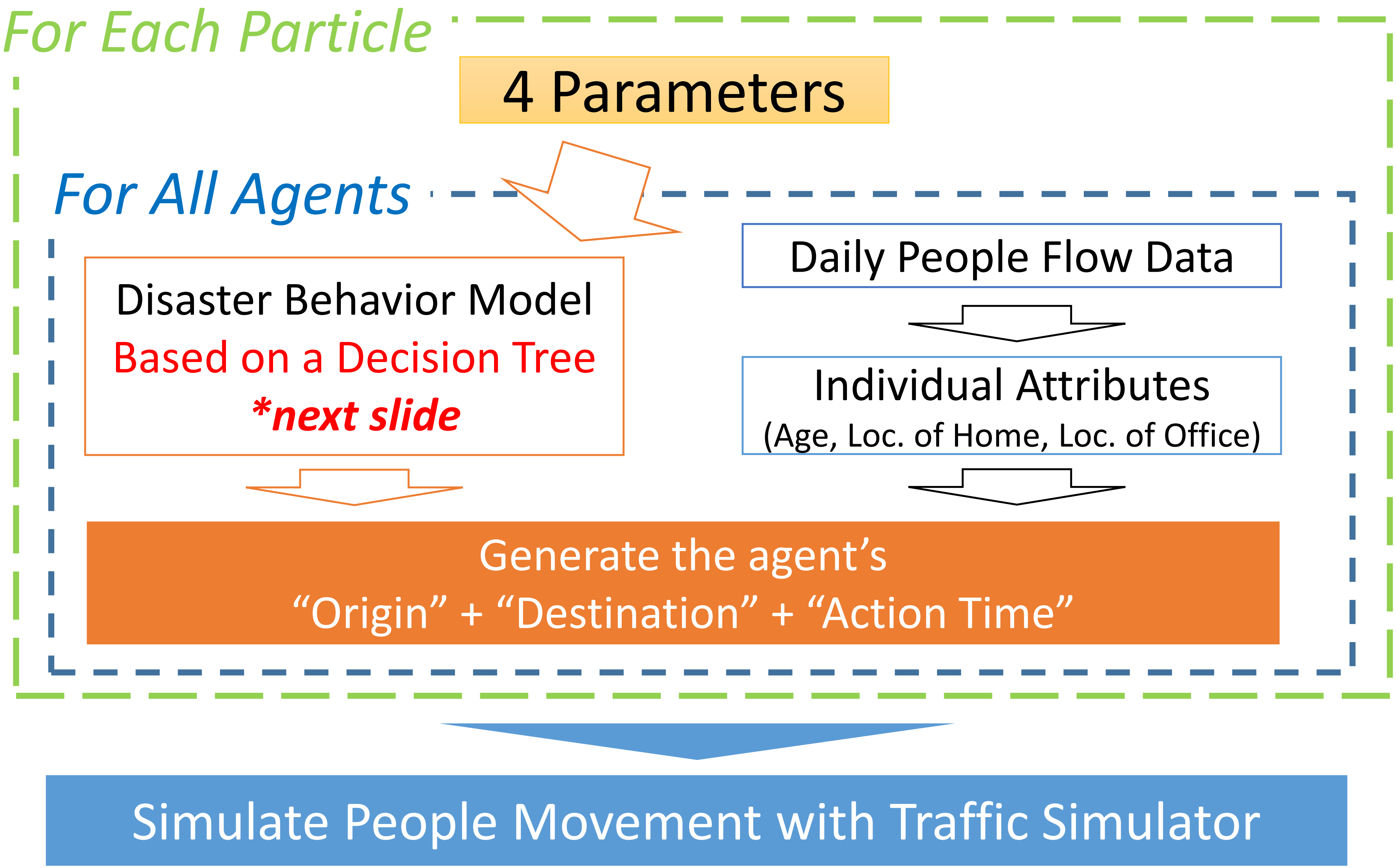
→ Advanced PF is more Suitable for People Flow Prediction

Data Assimilation

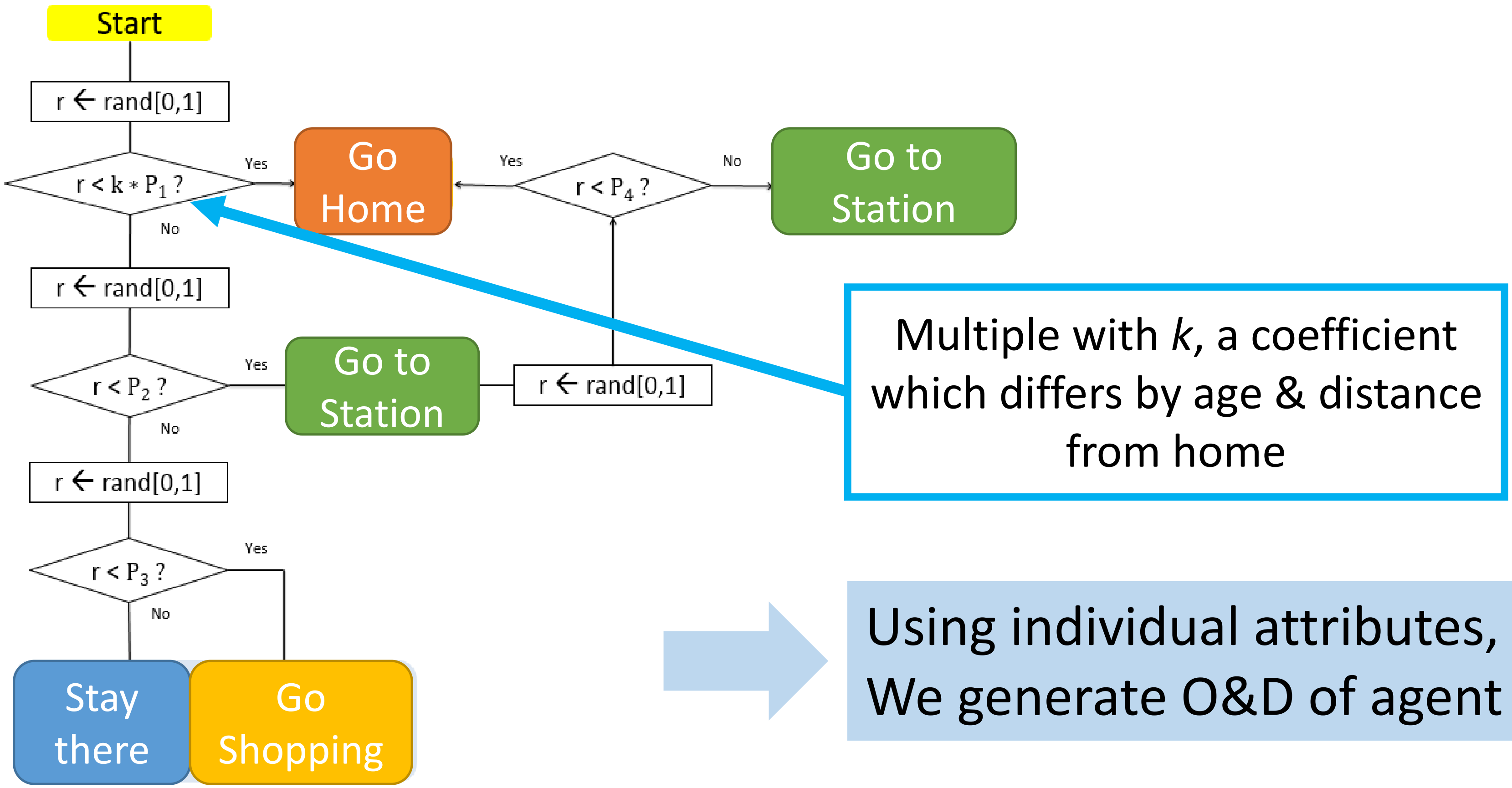
Combines Simulation and Observation Data for accurate prediction



Behavior Model and Simulation



Disaster Behavior Model



Decision Tree of the Disaster Behavioral Model

Using individual attributes, We generate O&D of agent

This Behavior Model was made based on Questionnaires of Disaster Victims in Japan [Ito *et al*.(2013)]

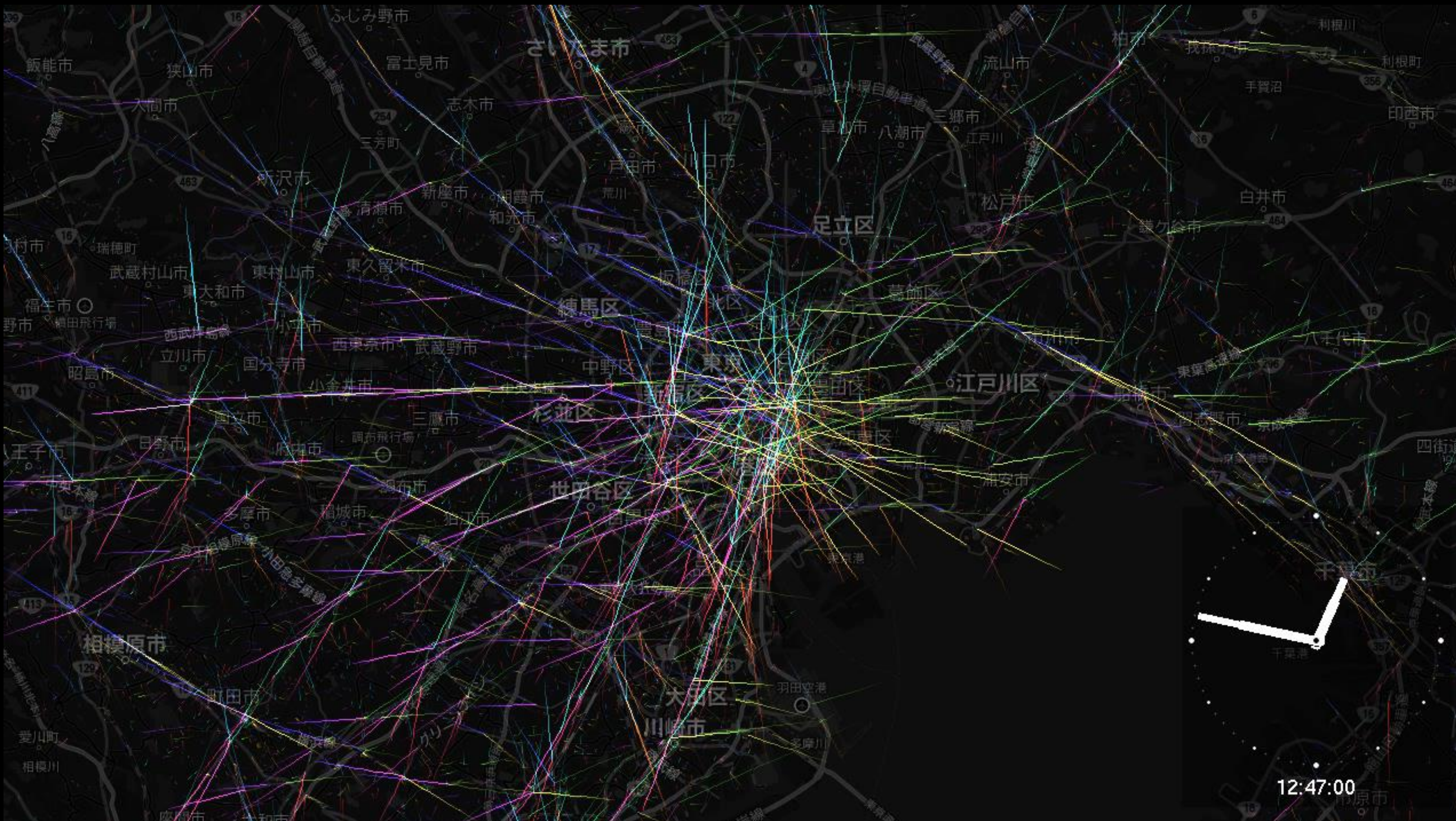
Verification Experiment

Can we predict the people movement in Metropolitan Tokyo on the day of the Great East Japan earthquake?

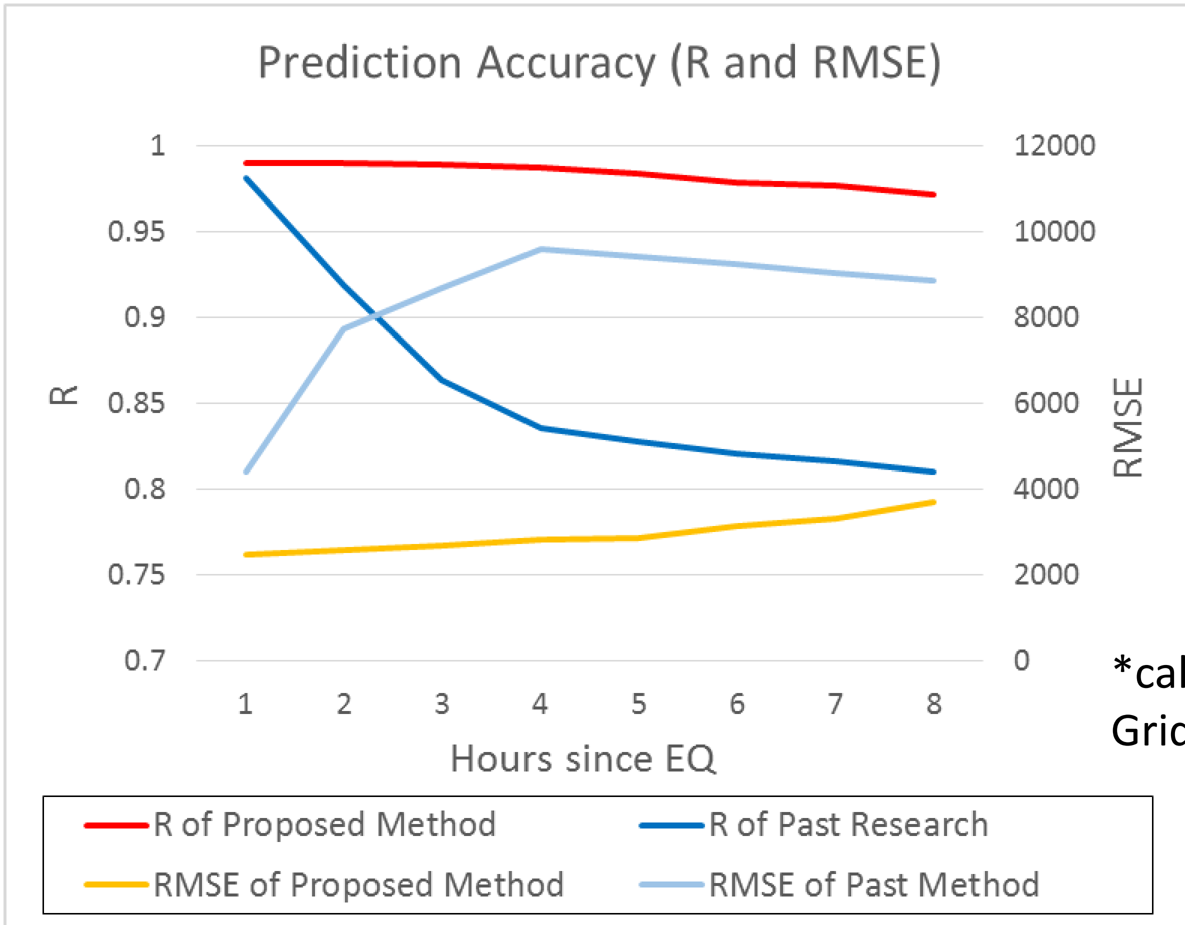
Experiment Settings

- Occurrence of EQ: 14:47:00 March 11th 2011
- Area: Metropolitan Tokyo
- Prediction of people movement until 23:00
- Observation Data: ZDC grid-aggregated Real-Time Data
- Railway: Stopped until 23:00

Visualization of People Flow on Earthquake Day



Prediction Accuracy of 1 hour ahead



*calculated by 500m Grid Aggregated data

- Past Research uses parameters calculated from “questionnaires”.
- Both R and RMSE are far better in our proposed method.

Behaviors of People on EQ Day

	To Home		To Station		Shopping	
Time	Number of People	%	Number of People	%	Number of People	%
15:47	428950	13.00	31950	0.97	132700	4.02
16:47	304400	9.22	45450	1.38	105200	3.19
17:47	261650	7.93	54300	1.65	91350	2.77
18:47	218300	6.62	69400	2.10	91400	2.77
19:47	204150	6.19	66950	2.03	100700	3.05
20:47	176900	5.36	71800	2.18	114250	3.46
21:47	160500	4.86	75000	2.27	123300	3.74
22:47	139650	4.23	83300	2.52	128850	3.90

- When compared to research done by the Cabinet Office, the number of people going home has high accuracy.
- As it gets darker, more people start to head to stations rather than their homes.

Conclusion

Conclusion

- We proposed a method to accurately predict real-time people movement in a disaster situation.
- We introduced a new particle filter method suitable for people movement prediction.

✓ In the experiment, we successfully predicted the population distribution with a high accuracy of R=0.97

✓ Also, the analysis of people movement was successful and we were able to know not only "how", but also "for what reason" the people moved by using a white-box model.

Future Work

➢ Application to other disasters (tsunamis, typhoons, etc.)

➢ A method to predict people movement when observation data is fragmented.

Thank you so much!

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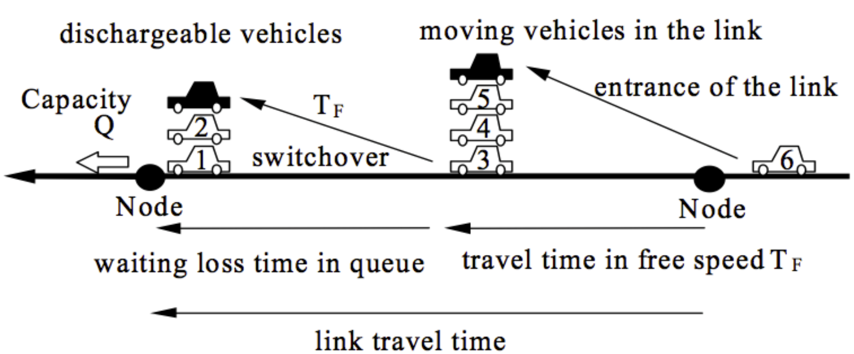
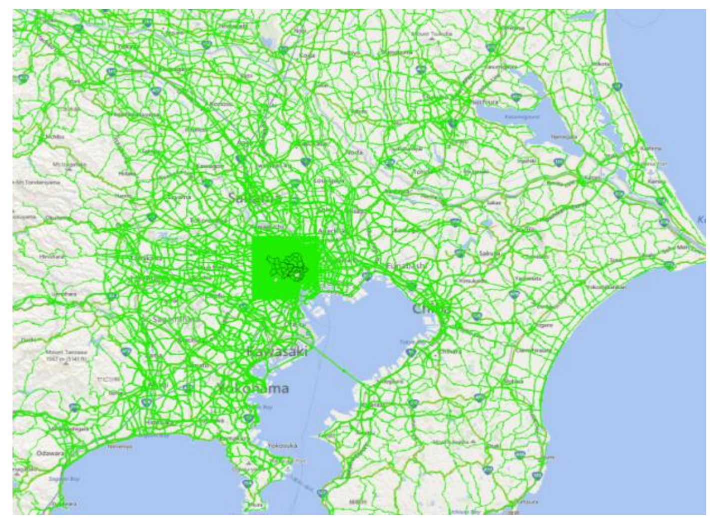
Appendix 1. Simulation

- Simulator has the road network and agents.
- Transportation mode consists of walk, car, train.
- OD set is generated by the behavior model.
- A route of each agent is determined by Dijkstra method.

  → Considers road congestion with a queueing algorithm

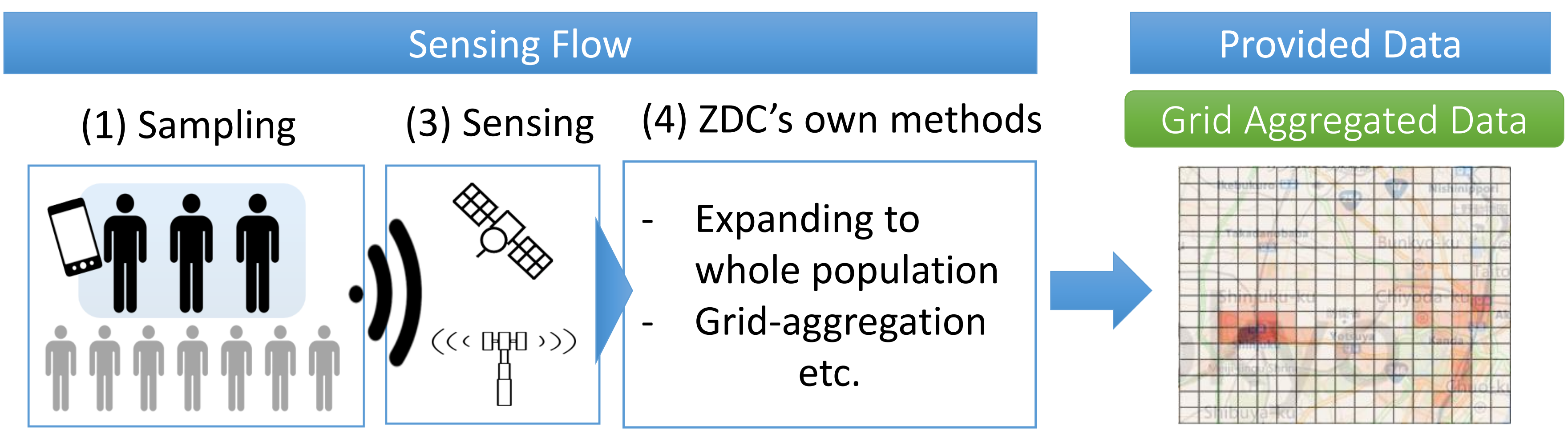




Road Network Data (green)

Appendix 2. Real Time Observation Data

- As observation data, we used data provided by Zenrin Data Com (ZDC, a Japanese company)
- ZDC gathers GPS data from individuals who have agreed to provide their location data
- Then, ZDC expands the samples to the whole population
- ZDC provides the data as grid-aggregated data to preserve privacy of the users.



Appendix 3. Related Work with PF

- P. Cheng, Z. Qiu, and B. Ran. Particle filter based traffic state estimation using cell phone network data. ITSC, 2006.
- Sasaki, “Analysis of traffic change using state space model”
- Herring, Ryan, et al. "Estimating arterial traffic conditions using sparse probe data." ITSC, 2010.
- Nakamura, “People flow estimation in Urban area using Particle Filter”

This work is the first study predicting the

Real-time People Distribution in Disaster time

by Data assimilation using mobile phone-data