

ISP 2016 Lyon, France

November, 3-4, 2016

Social CPS:
*Its Concept and Practical Experience Acquired in the
Demonstrative Experiments*



Jun Adachi

November 4, 2016

National Institute of Informatics, Japan

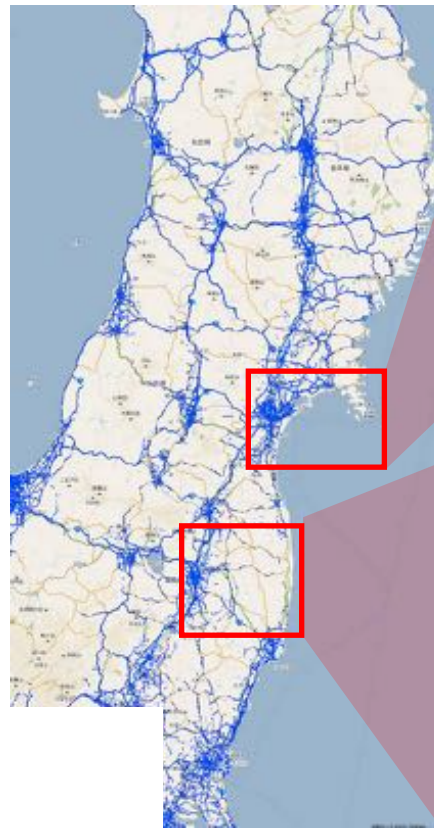
A Social System Service After a Severe Disaster

Online information of **passable roads** after the Great East Japan Earthquake of March 11 in 2011



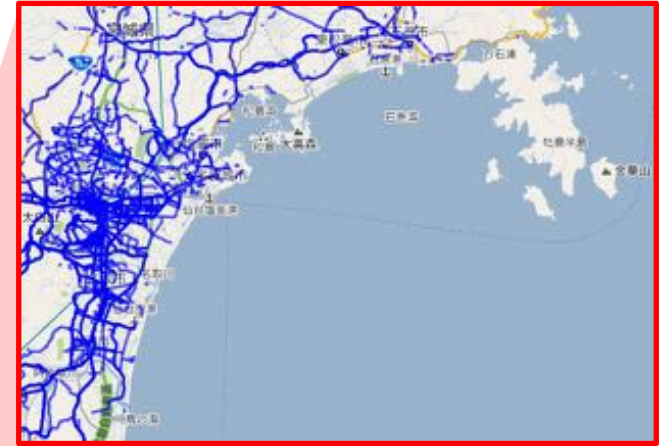
Official road information

The above figure is officially provided on March 20, 2011 by the Ministry of Land, Infrastructure, Transportation and Tourism



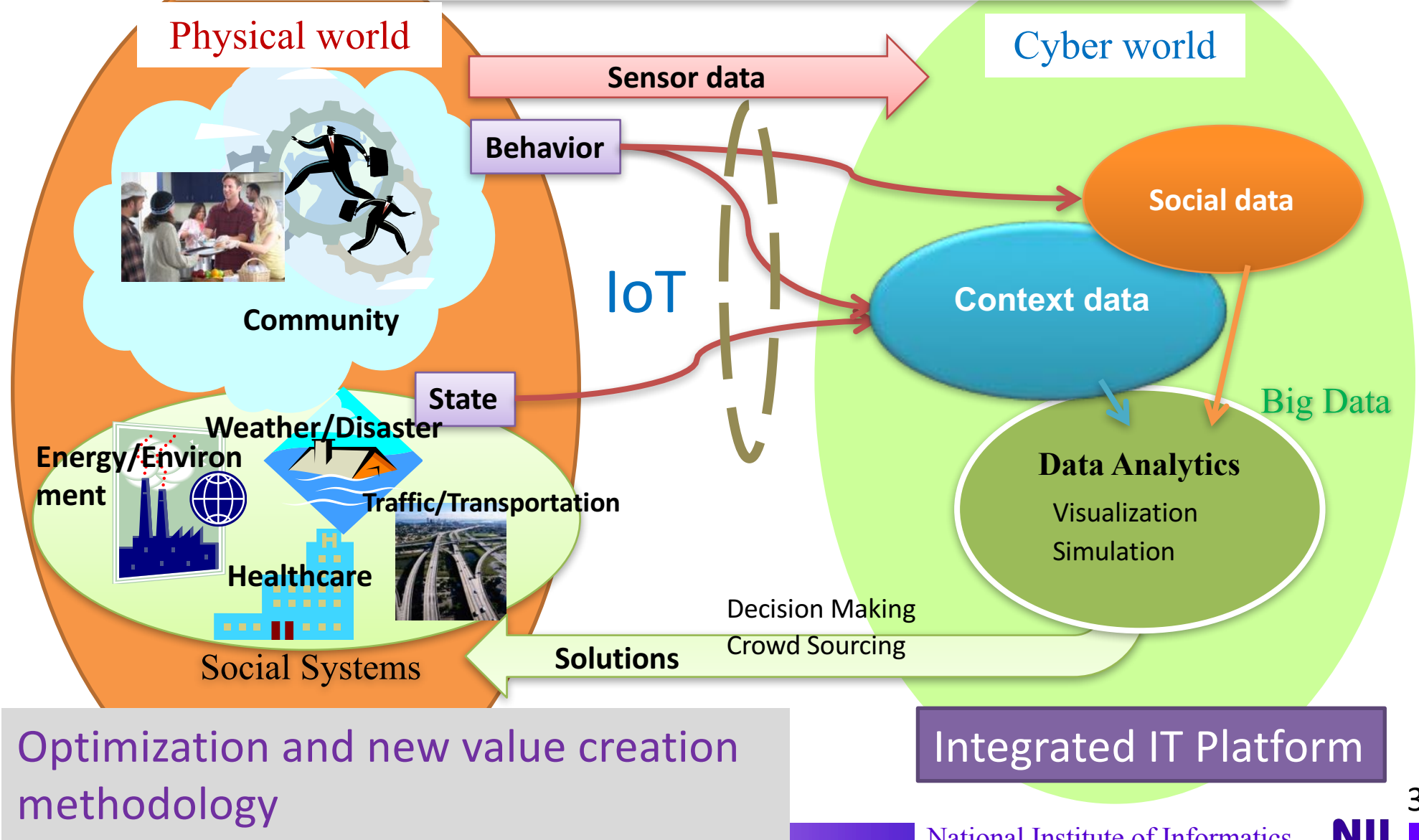
Information provided by automobile companies

The real time information of travelable roads as of March 20, 2011 based on vehicle travel information jointly provided by Honda, Pioneer, Toyota and Nissan.



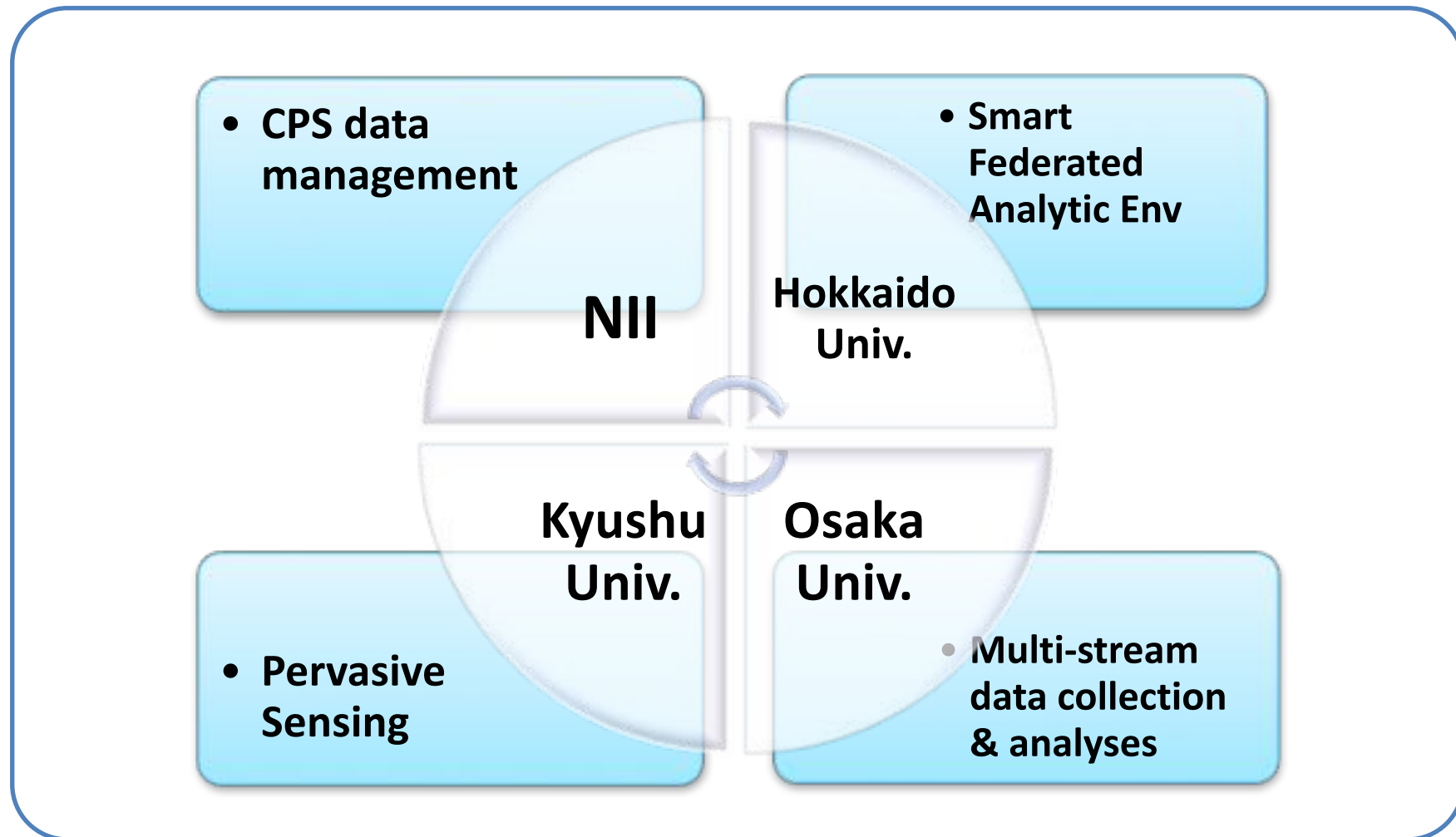
Cyber-Physical System for Social Systems Optimization

Grasp the physical world in real time via sensor data.
Give feedback with an optimal solution for the social systems



CPS-IIP: *Integrated IT Platforms for Cyber-Physical Systems to Accelerate Implementation of Efficient Social Systems*

September 2012 -- March 2017 funded by MEXT



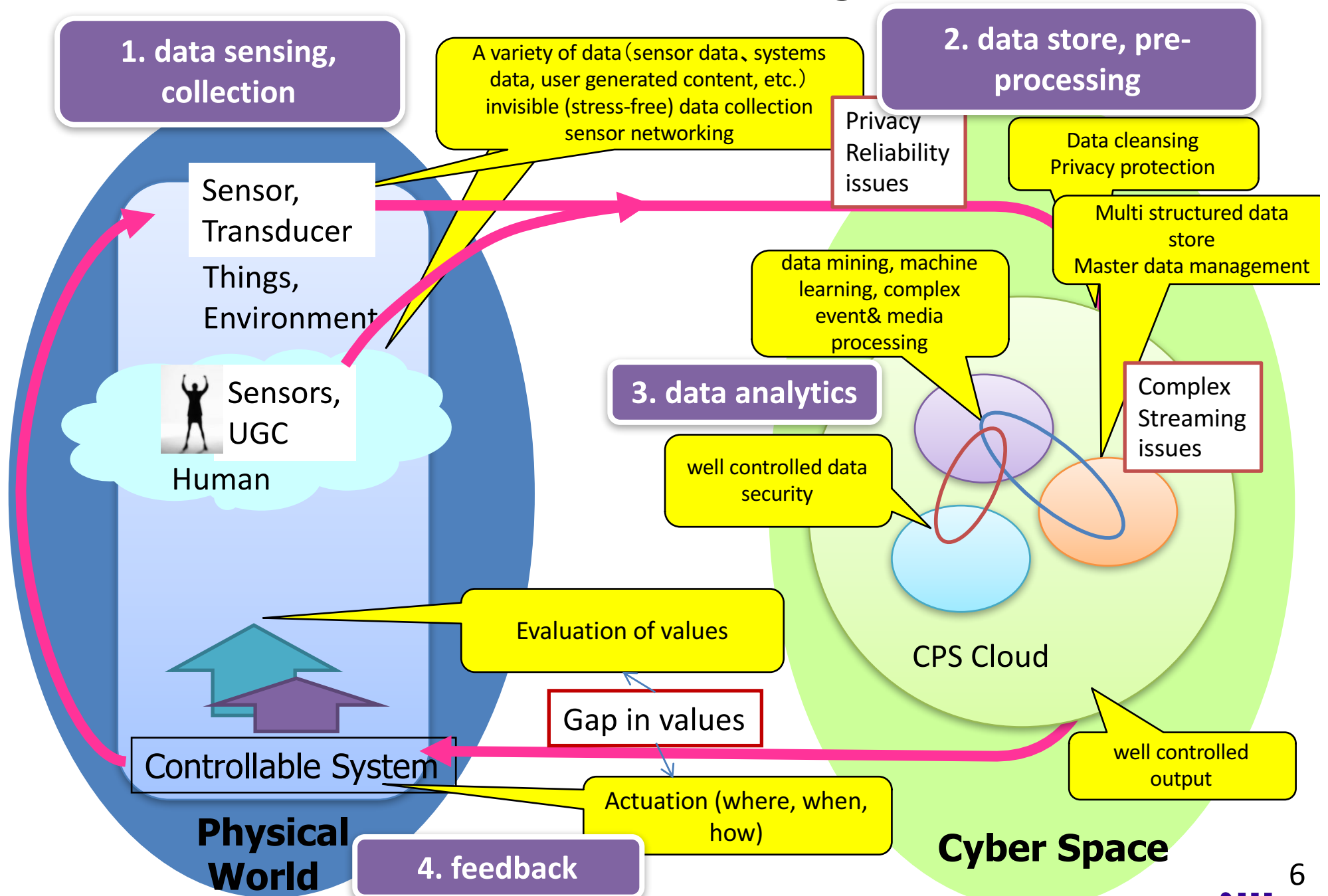
Goals of the CPS-IIP Project

“To understand large complex systems in the real world via *BigData* and provide optimal solutions based on their context”

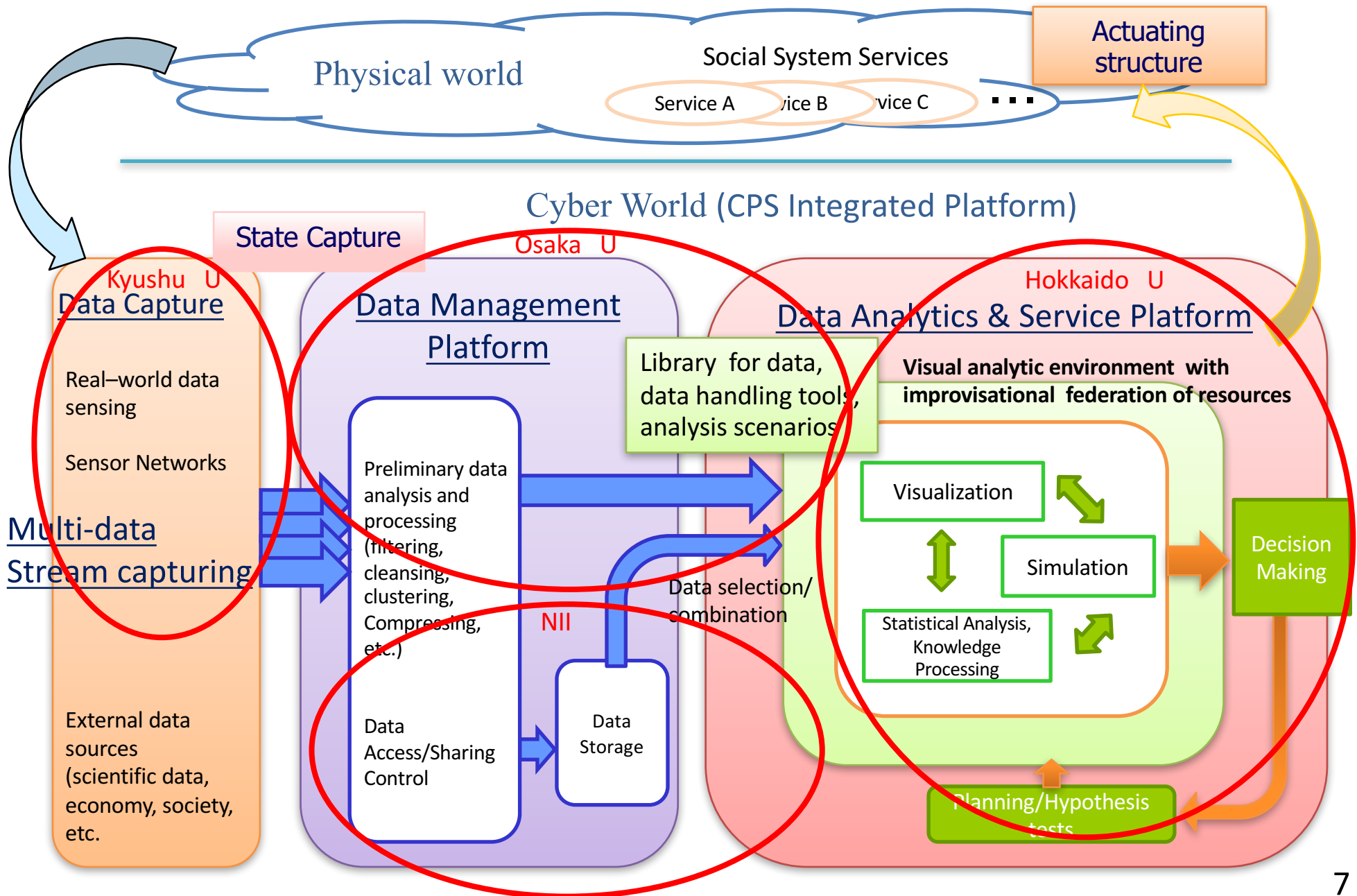
Real world: Building, Campus, City . . .

- Pervasive data sensing mechanism for diverse data streams and real-time feedback functions
- Scalable & secure data management Platform
- Complex data analytics & decision making support platform
 - Exploratory visual analytics utilizing flexible combination of various data sources and analytics tools

General Issues in CSP/Big Data



CPS-IIP Structure



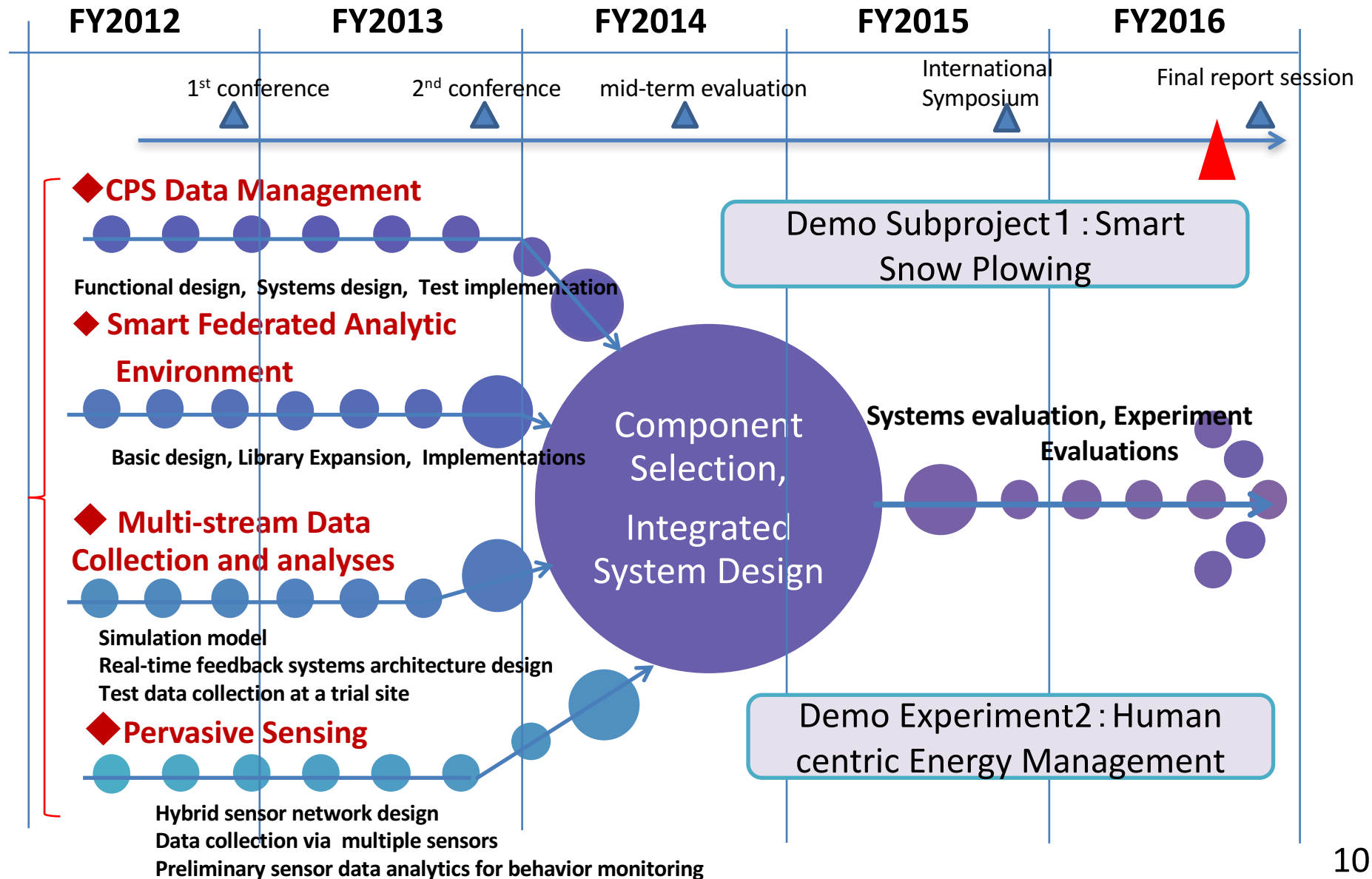
Real world Data Collections for CPS-IIP

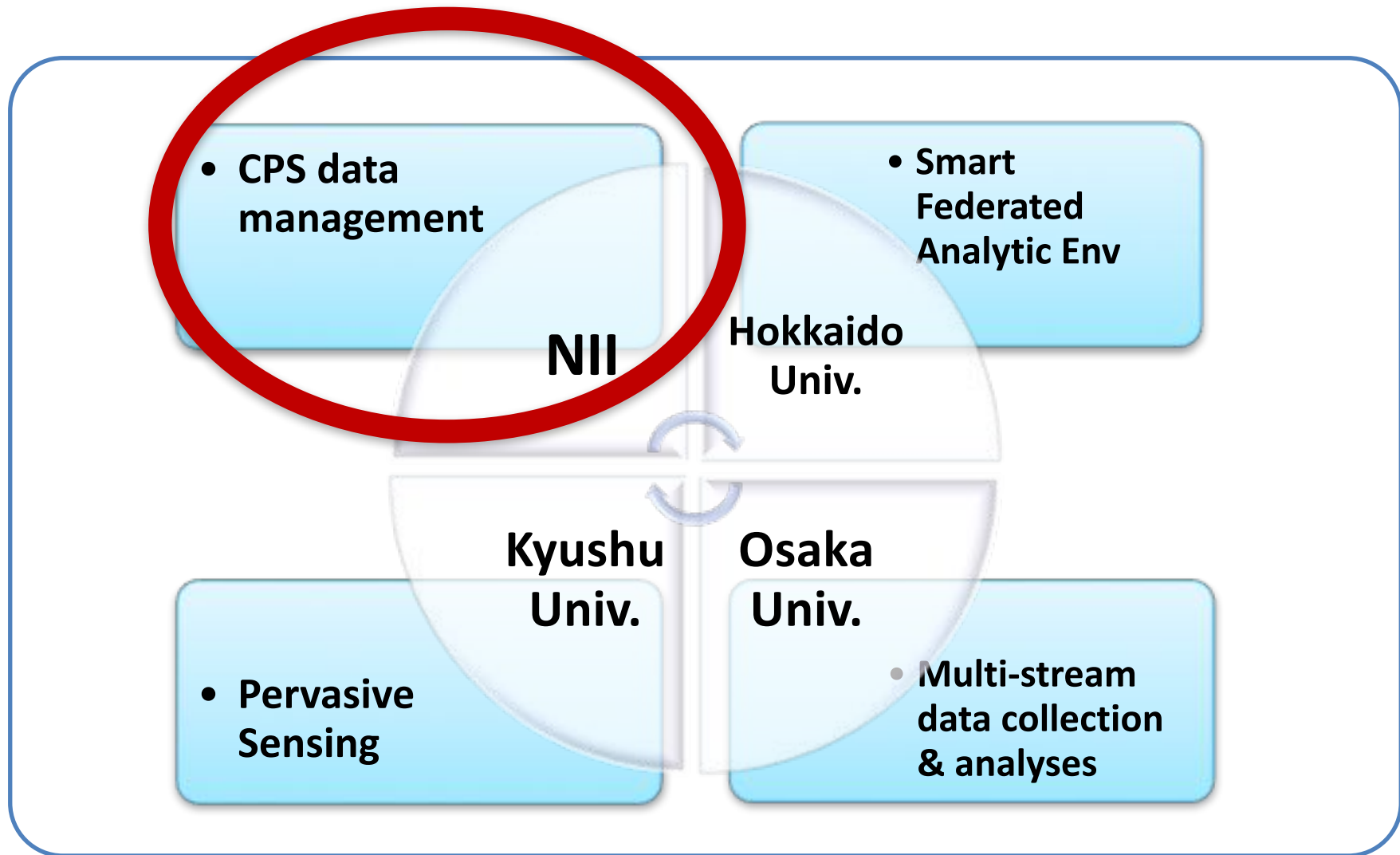
Category	Data & source
Location info of vehicles	Probe car data, Taxi probe data
Location info of humans - GPS information - Incoming/outgoing info at stations	Location information from smart phone application Usage information of IC cards in subway passengers
Broadcasting media info	TV program archive of 7 major Tokyo stations of 200k hours for 3 years (150TB)
Student behavior info - IC card usage	Captured in Kyushu Univ. campas
Environmental and weather info	Snowfall, snow removal from Sapporo city and Japan weather association Real-time weather info from the satellite
Power consumption info	Smart meters in campuses of Kyushu and Osaka Univ.
Communication traffic info	NII's SINET

Potential Service Applications of CPS-IIP

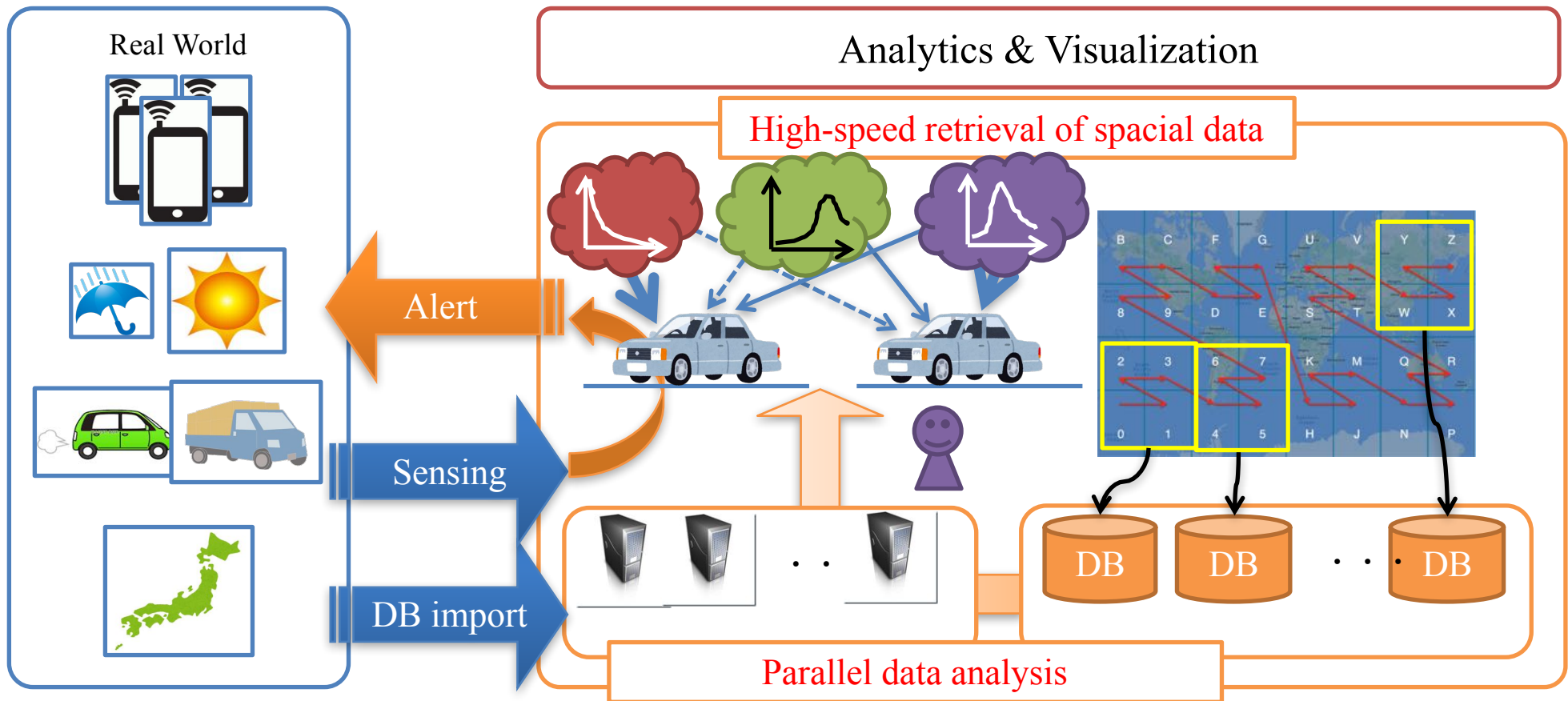
Service Field	Captured Data	Analytics	Feedback/Value
Snow plowing and removing in a large city	<ul style="list-style-type: none"> - movement of humans and vehicles (GPS) - complaints from citizens - snow plowing state (reporting) 	<ul style="list-style-type: none"> - Visualization of traffic conditions under snowfall and snow plowing - Method: Open smart federation architecture - Open Library w/ software components and data sets 	<ul style="list-style-type: none"> - Info dissemination thru SNS to citizens - Snow removal operation management: Optimization of the time and place for clearance.
ITS	<ul style="list-style-type: none"> - movement of humans and cars using GPS and other sensors 	<ul style="list-style-type: none"> - Vehicle behavior → road congestion and accident detection - integration onto GIS 	<ul style="list-style-type: none"> - Traffic management via signal control - navigation for CO₂ reduction
Disaster Management	<ul style="list-style-type: none"> - Social systems sensing - Human behavior sensing 	<ul style="list-style-type: none"> - Simulation of human activities in the city 	<ul style="list-style-type: none"> - Evacuation support - Rescue support - Aid delivery control
Personalized energy saving on campus	<ul style="list-style-type: none"> - Visual sensor - Energy consumption sensors - IC card info 	<ul style="list-style-type: none"> - Modeling of human and vehicle movement - Power consumption modeling 	<ul style="list-style-type: none"> - Visualization of human behavior - Visualization of personal power consumption - Community energy management

Five-year Research Plan

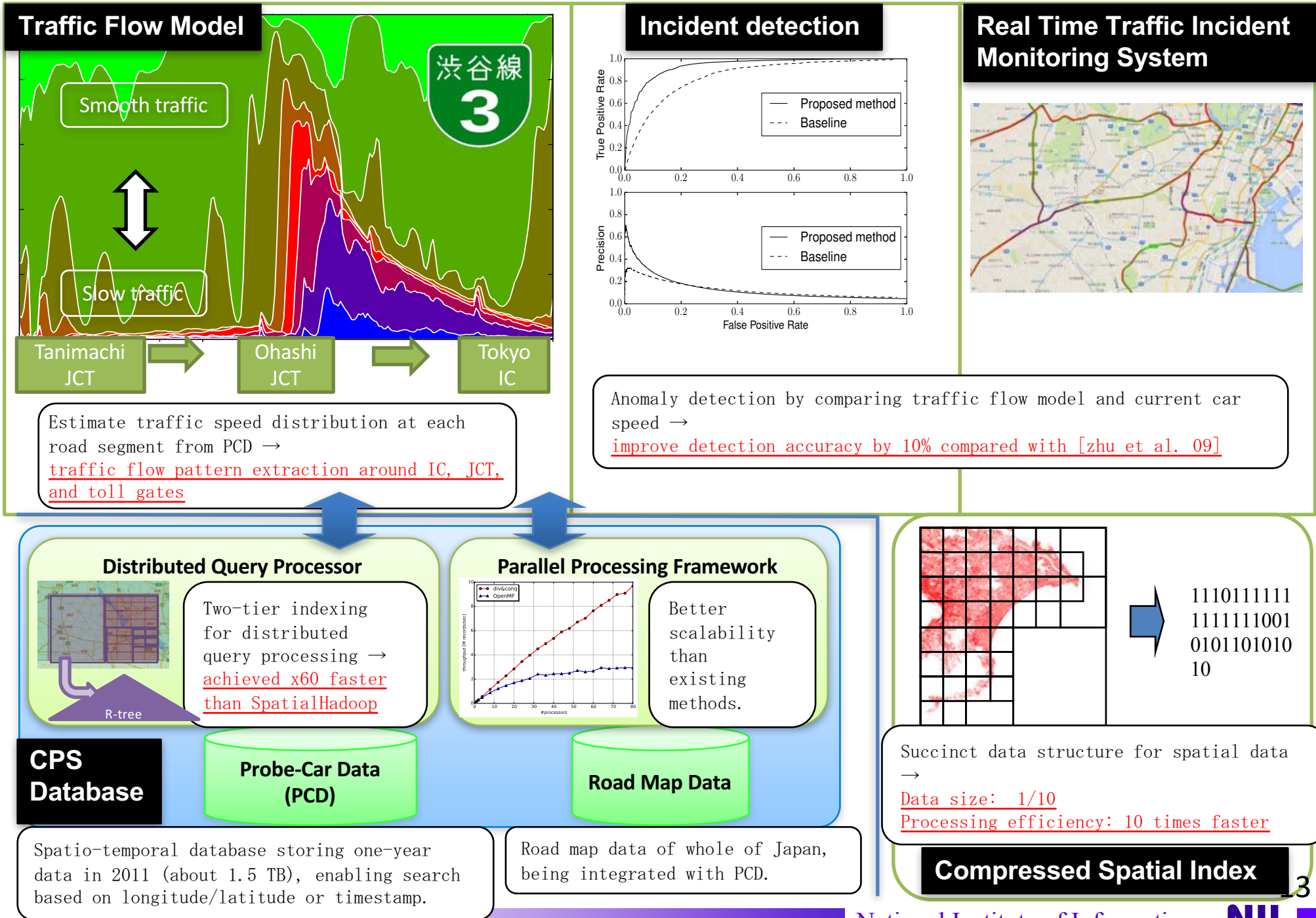




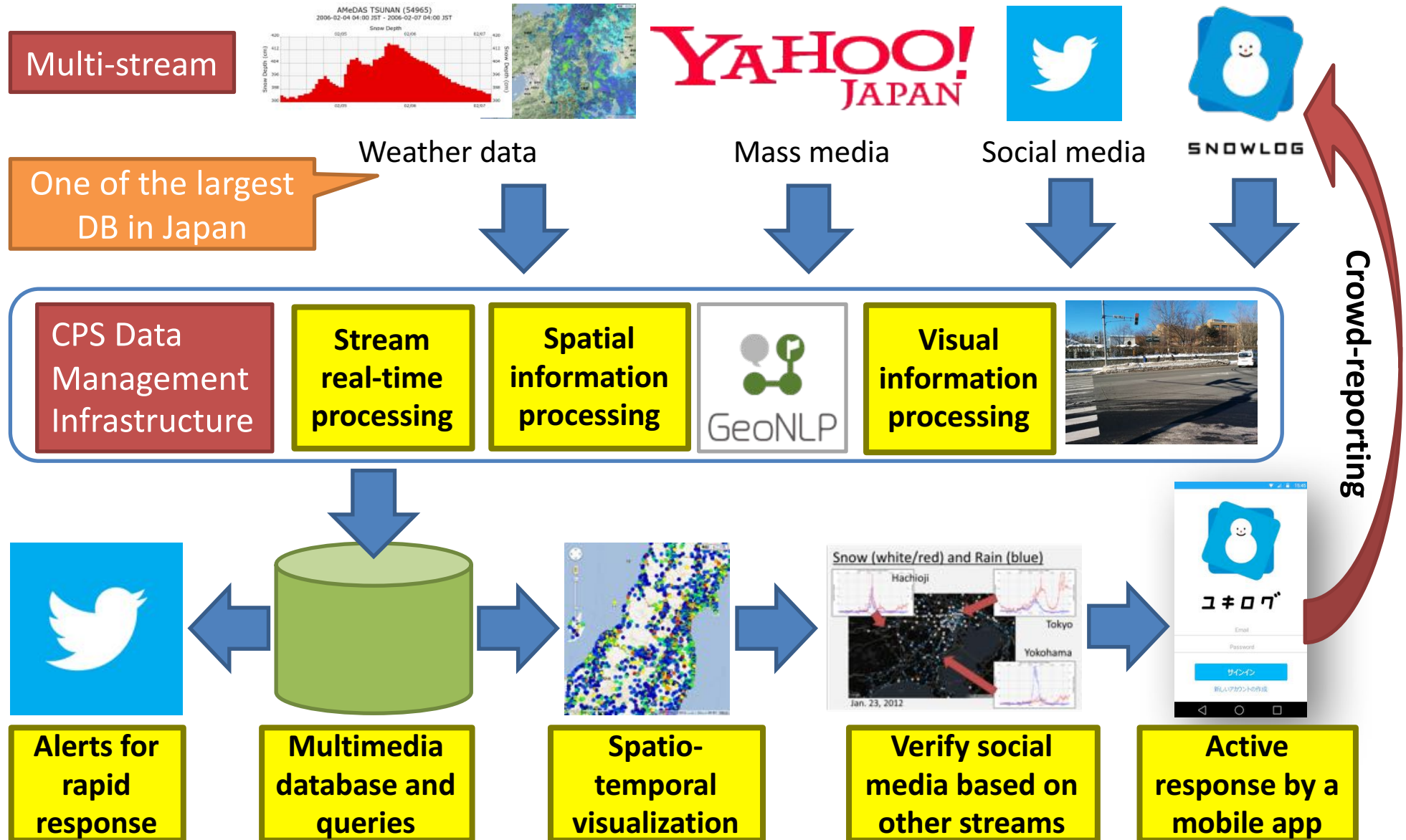
CPS-IIP Data Management and Analytics Platform



Infrastructure for Stream Data Management and Analysis



Visualization and Integration of scientific, social, and participatory data streams for smart snow removal



Crowdsourced Mobile Sensing

“crowdsourcing”

- the act of taking a task traditionally performed by a designated agent and outsourcing it by making an open call to an undefined but large group of people ([Howe 2006]).
- can take the form of peer production
- is also often undertaken by sole individuals (“collective knowledge”)

motivating citizens to participate in the service by providing useful functions and information



Crowdsourced Mobile Sensing



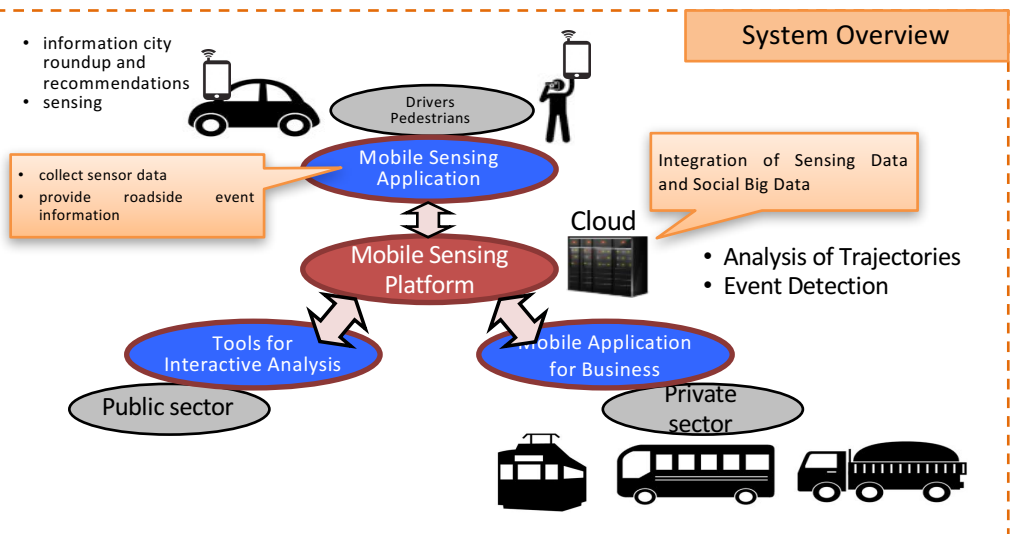
Driving Recorder Application

[sensing]

- recording sensor data and movie while users drive
- sending drive logs and movies to the service platform
- enabling users to post events that they realize

[showing information]

- event information collected from users



Collected Data

• Location

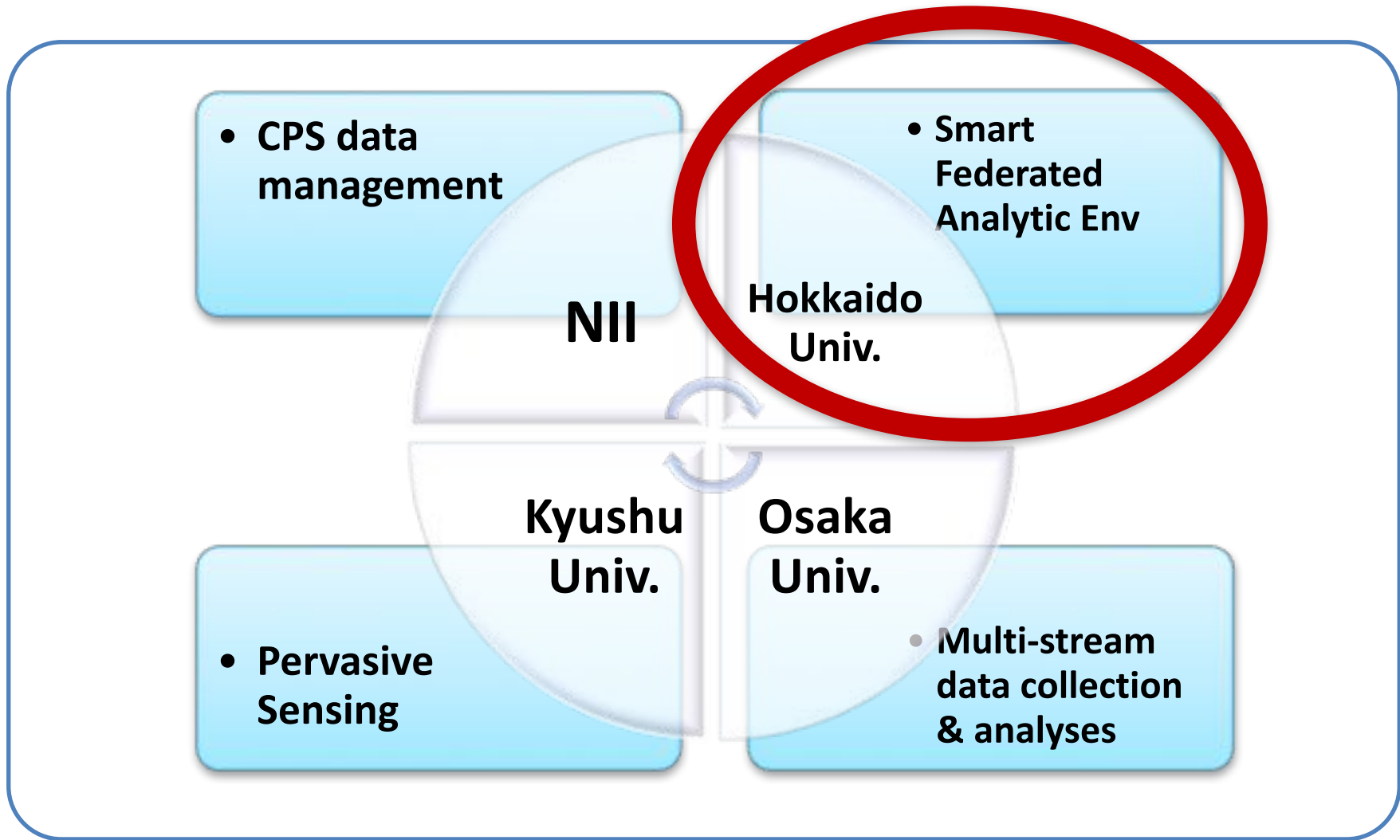
- latitude, longitude, altitude

• Move

- acceleration (x,y,z)
- gyro (x,y,z),
- course, speed

• Scene

- movie (1280x720, mp4)



Social CPS Smart Federation Integrated Platform and its Software Technologies

Goal : Social CPS Smart Federation Integrated Platform

Technologies to develop :

- ❖ Federation technology / visual analytics platform architecture / smartphone-based crowd sourcing of real time location data and image data
- ❖ Large scale social CPS data warehouse / mobile SNS
- ❖ Social CPS Integrated Platform Architecture

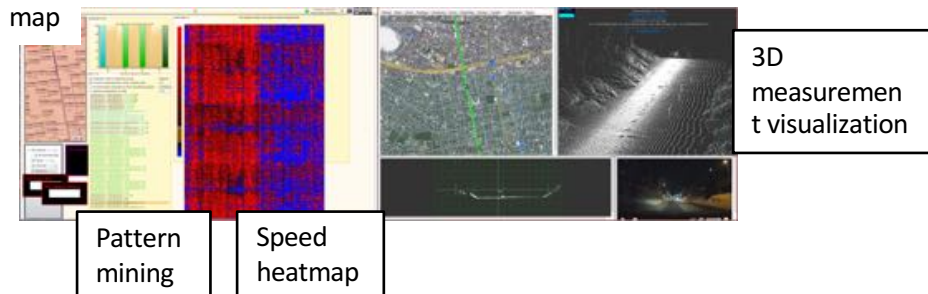
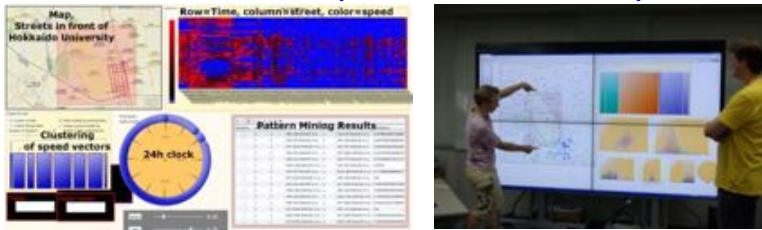
Smart federation platform architecture

Open publication of Web-top meme media system
WebbleWorld

Federating 10 tools and services within 10 min.

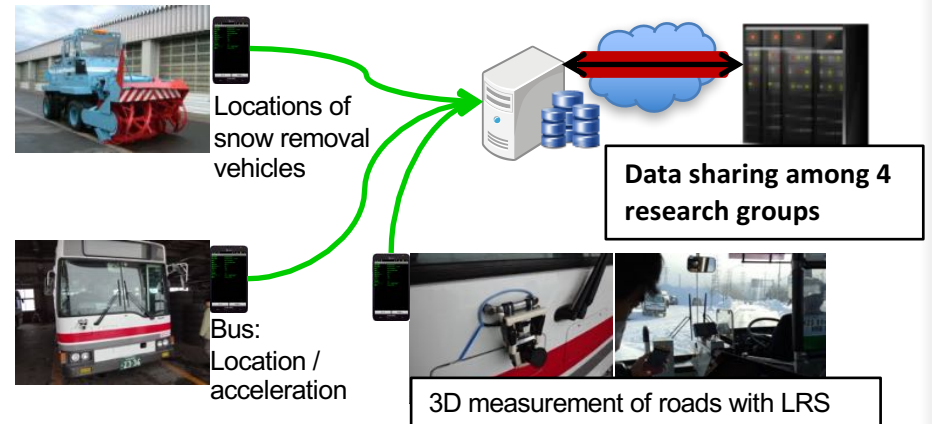
Visual Analytics Platform Architecture

- Geospatial Digital Dashboard with access to real data
- Coordinated multiple views and analyses framework



Exploratory visual analytics with Geospatial Digital Dashboard to detect traffic obstacles for pinpoint snow removal

Smartphone-based crowd sourcing of real time location data and image data
Real time capturing of locations of buses and snow removal vehicles



Large-scale social CPS data warehouse

- NoSQL database and its interface
- Web-based data acquisition and data visualization viewer

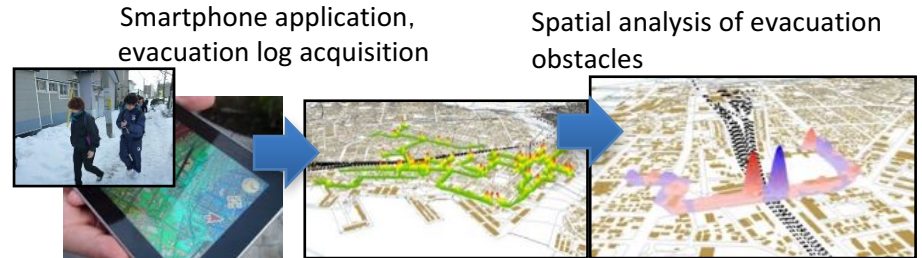


Large-scale social CPS visual analytics service library

Goal : To enrich the large-scale social CPS visual analytics service library
Technologies to develop :

- ❖ Registration of existing analysis and visualization tools and services
- ❖ Development of new analysis and visualization tools and services
- ❖ Implementation of real-time analysis tools

Spatial analysis of behavioral obstacles

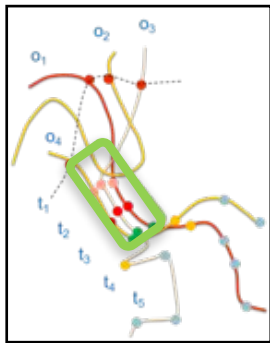


Smartphone application, evacuation log acquisition

Spatial analysis of evacuation obstacles

Summer (red) + winter (blue)
 Identification of winter time obstacles

High-speed trajectory mining and flock pattern discovery



flock pattern

750 time faster

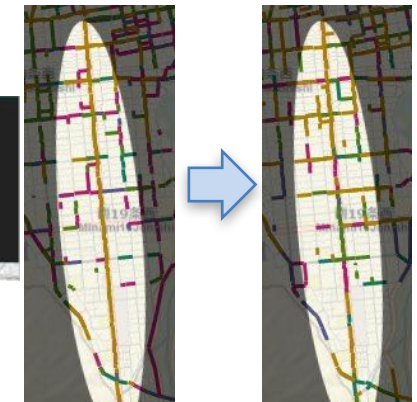
(Gudmundsson et. al. AGIS2006)



Typical route change discovery of traffic, Applicable to anonymous trajectory data

Visualization of traffic jam, weather radar data, estimated amount of snow removal, and snow removal trajectory

Clustering analysis of road links



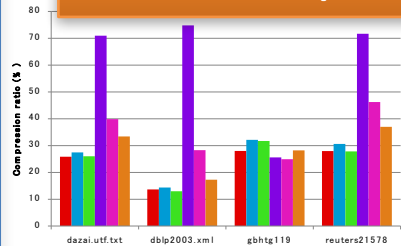
Before snowfall After snow fall

Daily change of average speed in each road link

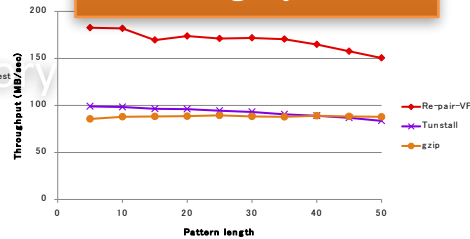
Identifying traffic jams after snow fall

Data stream compression for pattern mining without decompression

Better compression than Gzip

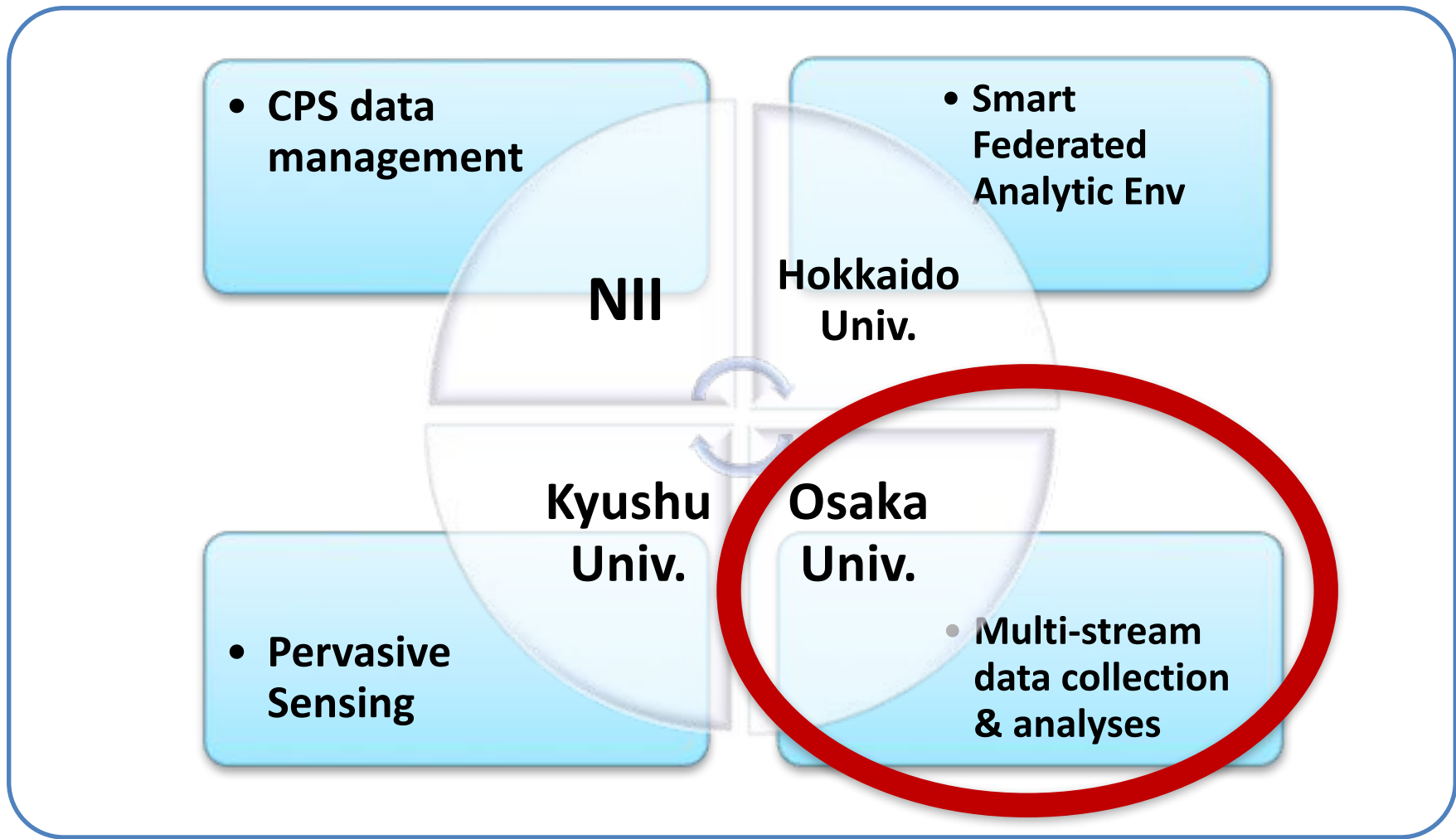


Two times faster retrieval than Zgrep



- compression and retrieval of trajectory data
- compression of log stream data

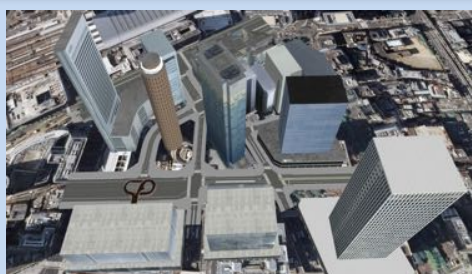
Generic wrapping of analysis tools in R, Octave, Ruby into components



Modeling, Simulation and Visualization for Constructing Smart Cities/Buildings

- ❖ Urban sensing for precise re-production of pedestrian/vehicular mobility in target areas
- ❖ Usage of simulation for future city planning and evacuation planning at emergency situations
- ❖ Visualization of simulation results

3D City Model + Crowd Behavior Sensing



Osaka Station Plaza



3D model of Grand Front Osaka



Evacuation Planning at Osaka Underground Mall



Modeling of Osaka underground mall (500m×500m) and pedestrian flow simulation based on crowd sensing

Urban Sensing/Simulation Technology

Laser Range Scanner



of visitors for buildings

Security Camera



Pedestrian flow Simulation

Visualization



Human-Centric BEMS Concept & Achievement

1. Human Tracking and Environmental Sensing Technologies

ACTIVE Lab.
アクティブラボ

demonstration for 33 months

The Lab.

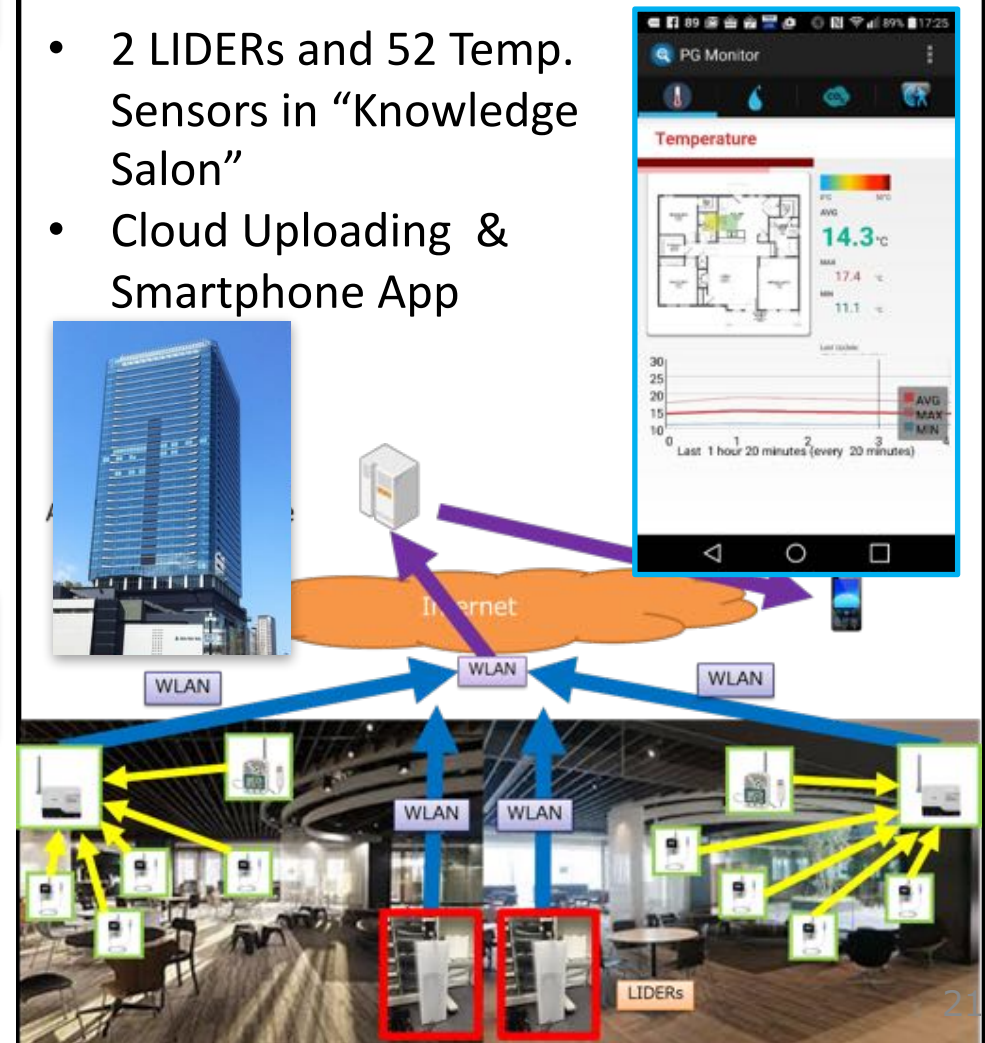
GRAND FRONT OSAKA North Area
3rd floor
KNOWLEDGE CAPITAL the Lab.

2. BEMS 2.0 Concept Establishment (New Metrics Design and Feedback Control)

- productivity-based energy efficiency
- human-oriented thermal comfort
- CFD-based feedback function

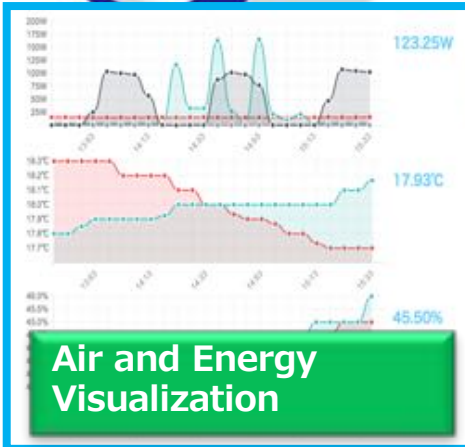
3. BEMS 2.0 Proof of Concept

- 2 LIDERS and 52 Temp. Sensors in “Knowledge Salon”
- Cloud Uploading & Smartphone App

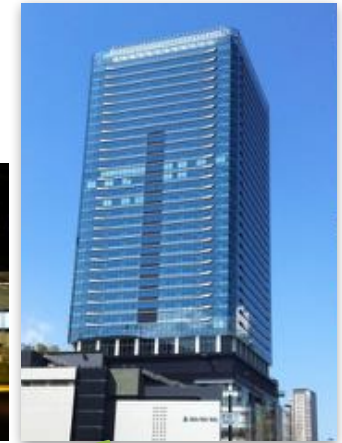




Hitonavi



"The Lab" in Grandfront Osaka (since Apr. 2013)



Energy Monitor

Air Sensors

Smartphones

Range Scanner (30m×270°)

Range Scanner (30m×270°)

Digital Signage Display

Too hot here?

Wonderful!

Come to see us! (>_<)

ISCA 2013 佳作賞

INTERNATIONAL STUDENTS CREATIVE AWARD 2013

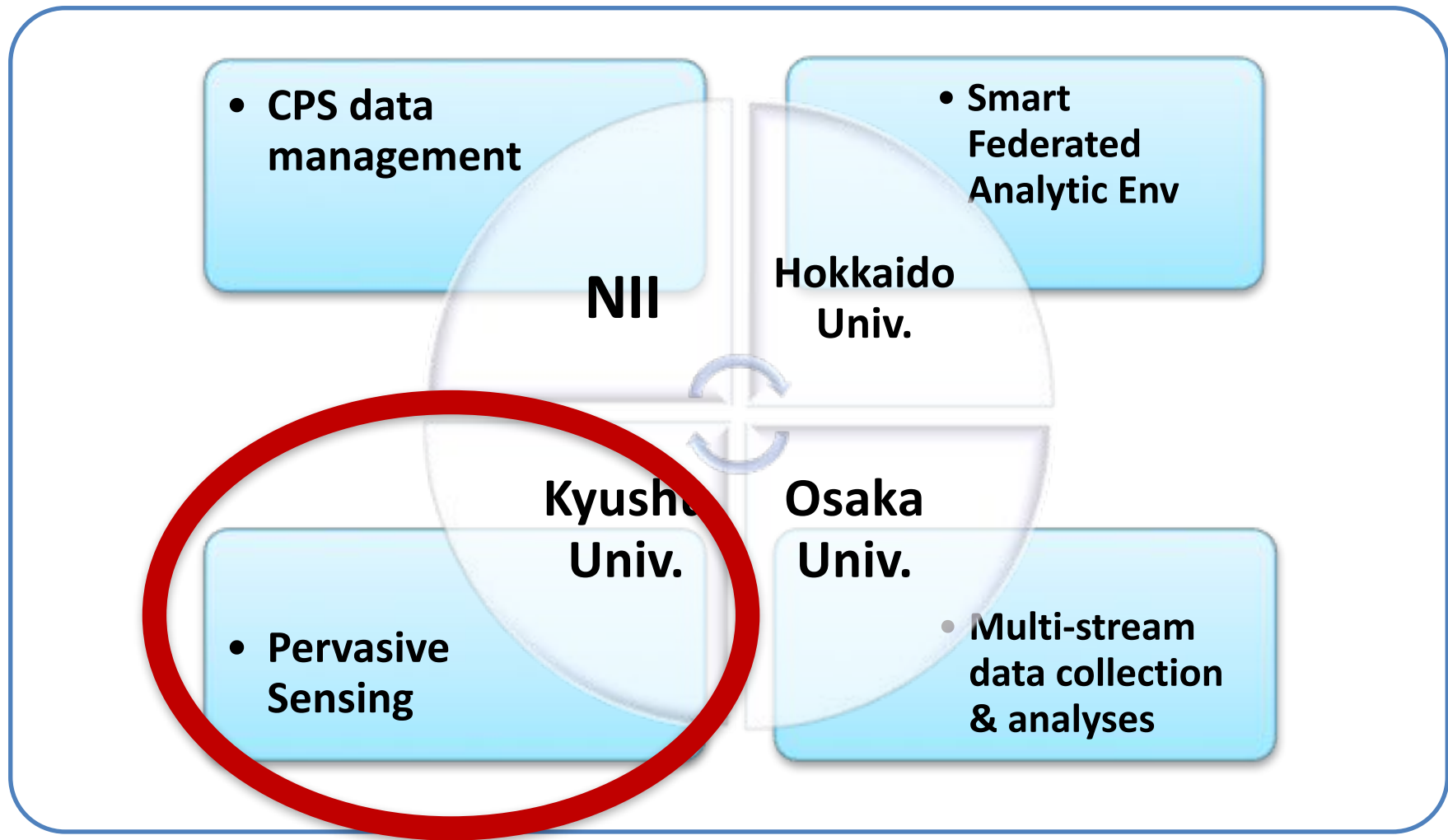
ISCA 2013 受賞作品発表会・上映会

情報処理学会 DICOMO2013 野口賞

KNOWLEDGE CAPITAL

22 大阪大学 OSAKA UNIVERSITY

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<http://cps-osaka.org/hitonavi/>



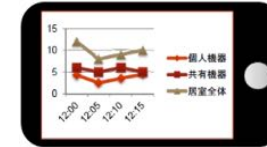
Pervasive Sensing

- Adaptive Sensor Network on Campus -

Objective : Construction of real-time social sensing system

Issues :

- ❖ Measurement of the position for each person by camera, Wi-Fi AP, ID card reader
- ❖ Measurement of environmental information such as temperature
- ❖ Integration of sensing data for grasping human activity



Visualization
Mining
Feedback

Provide API

Integration
• Person trajectory
• Personal power usage



Outdoor sensor node

- Self power generation
- Over 6Mbps

Ad-hoc private network

- High-throughput multistage relay
- Easy extension of sensing area and sensors

Integrated server



Camera server



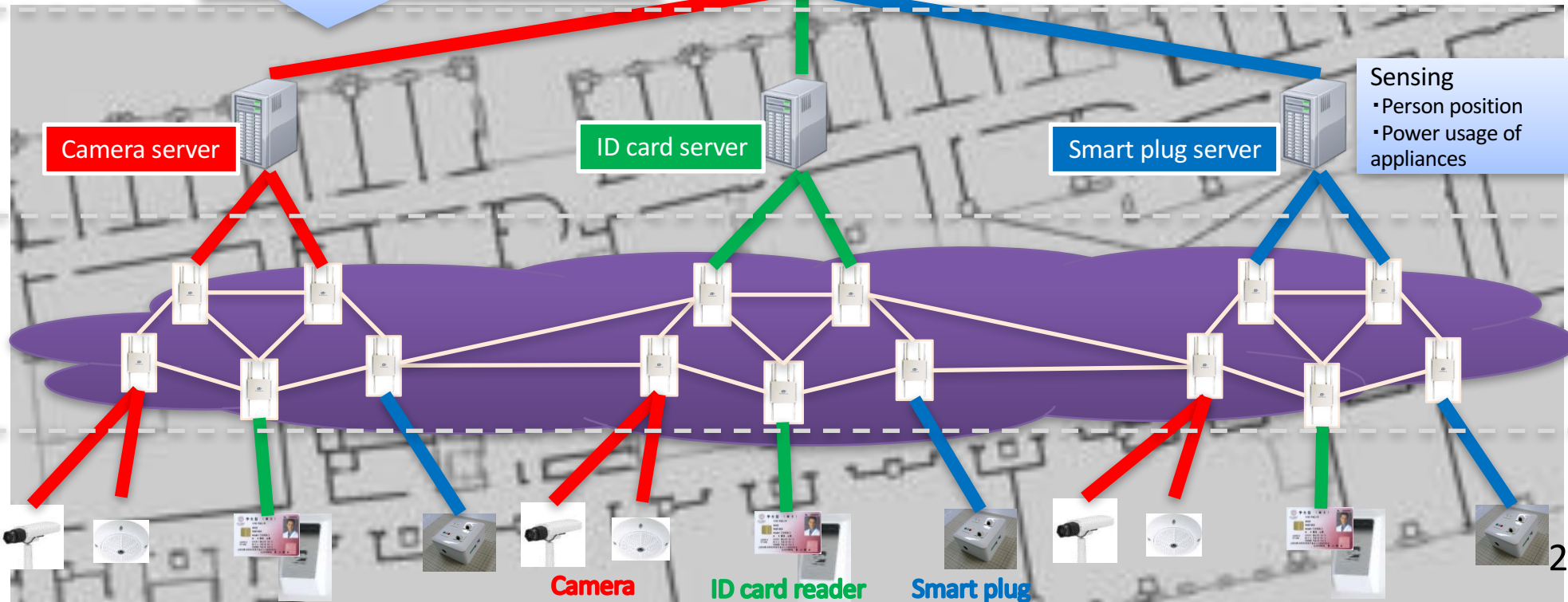
ID card server



Smart plug server



Sensing
• Person position
• Power usage of appliances



Data Analysis and Feedback for Efficient Energy Usage

Objective : Construction of feedback system for efficient energy usage

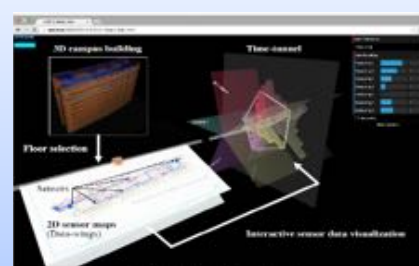
Issues :

- ❖ Analysis of the relation between person behavior and power consumption
- ❖ Visualization of sensing data for analysis and indication to user
- ❖ Support system considering acceptability for efficient energy usage

Feedback system



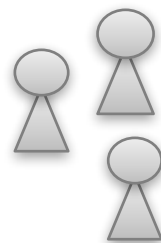
Visualization for user
Simple, easy to understand



Visualization for administrator
Advanced analysis

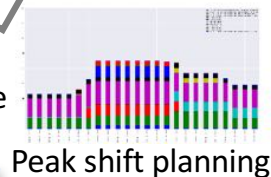
Arrival time to your laboratory
08 : 00
Leaving time from the laboratory
21 : 00
 Absent
Send

Input schedule



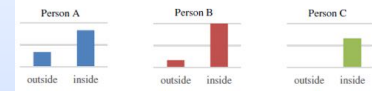
Peak shift system

Request for modifying schedule

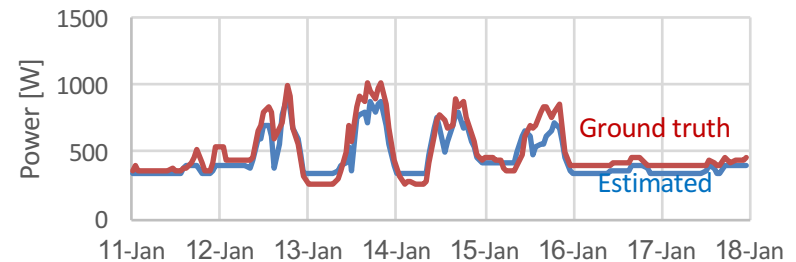
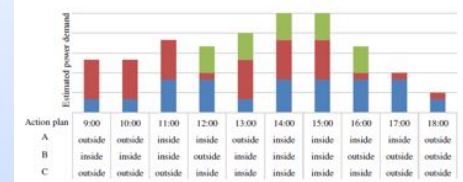


Peak shift planning

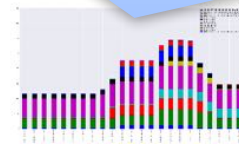
- Peak shift based on schedule change
- Balancing between efficiency of peak cut and time change of schedule



Power demand estimation based on input schedule



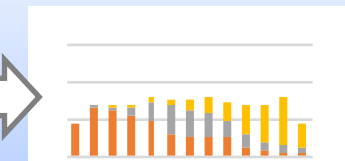
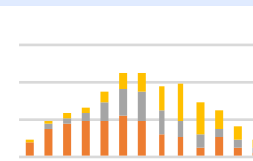
Estimated power demand



Power demand estimation

Future work

What kind of incentive is appropriate?



Cooperative peak shift between community

- **CPS data management**

- **Smart Federated Analytic Env**

Ongoing Demonstrative Subprojects

1. **Smart Snow Removal Operations**
2. **Productivity-based Energy Efficiency**

- **Pervasive Sensing**

- **Multi-stream data collection & analyses**

DEMO 1: Evidence-based Improvement of Snow Removal in Sapporo

Snow Removal in Sapporo as a Large-scale Complex Social Service

- Population: 1,920,739
- Annual snowfall: 597cm
 - The largest annual snowfall among the cities with more than 1M people in the world
- Annual budget for snow plowing and removing (2010): 14,729,000,000 yen (147,000,000 \$)
- 2nd last season: 22,000,000,000 yen (220,000,000 \$)
- Total distance of snow plowing and removing during a single night: 5,328km



Winter Road Situations in Sapporo

Winter road situations depends on weather, snow removal, and traffic in complex ways.



Improvement on

- Average speed of the traffic / Average delay of fixed route buses / Arrival time of emergency vehicles
- CO2 emission from traffic jams
- Annual cost of snow removal
- Winter traffic accidents

Evidence-based quantitative account on

- Traffic disturbance by snowfalls
- Snow removal effect

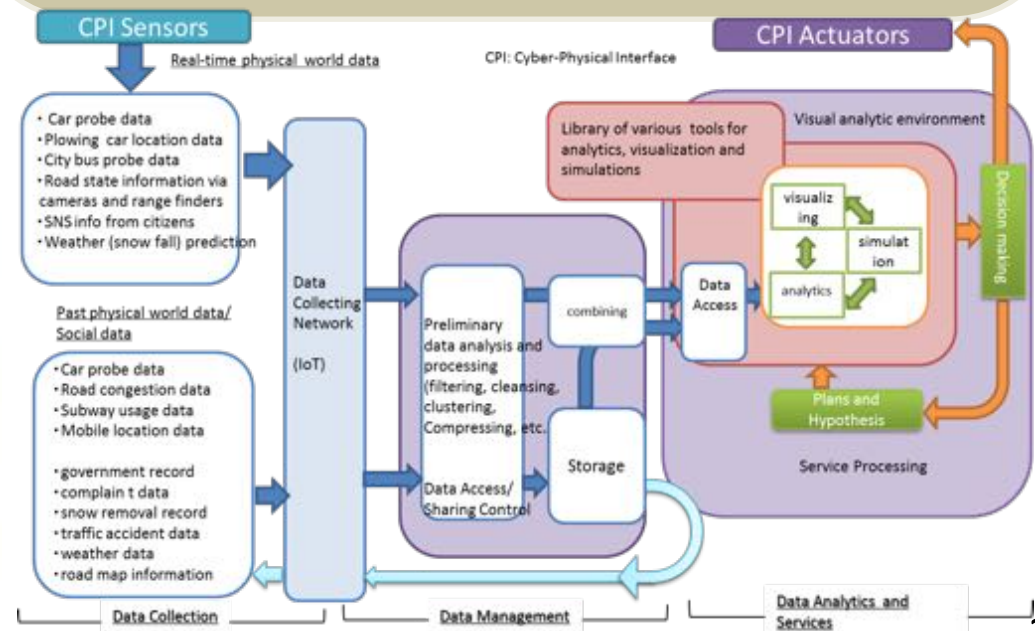
Information sharing between the city government and citizens

Citizen → Government

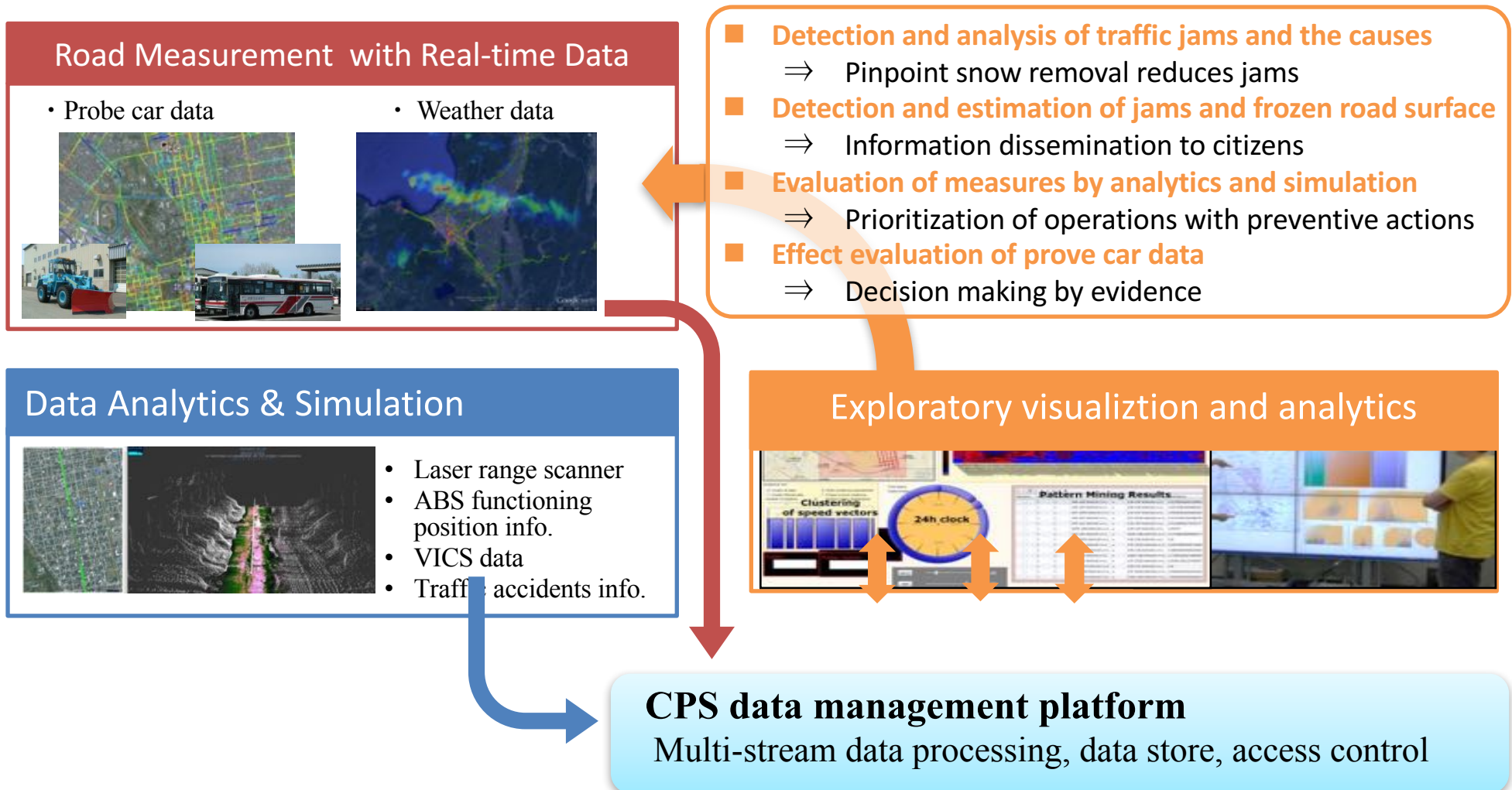
- Complaints / road conditions and accidents

Government → Citizens

- Conditions of road/ traffic / snow removal / weather

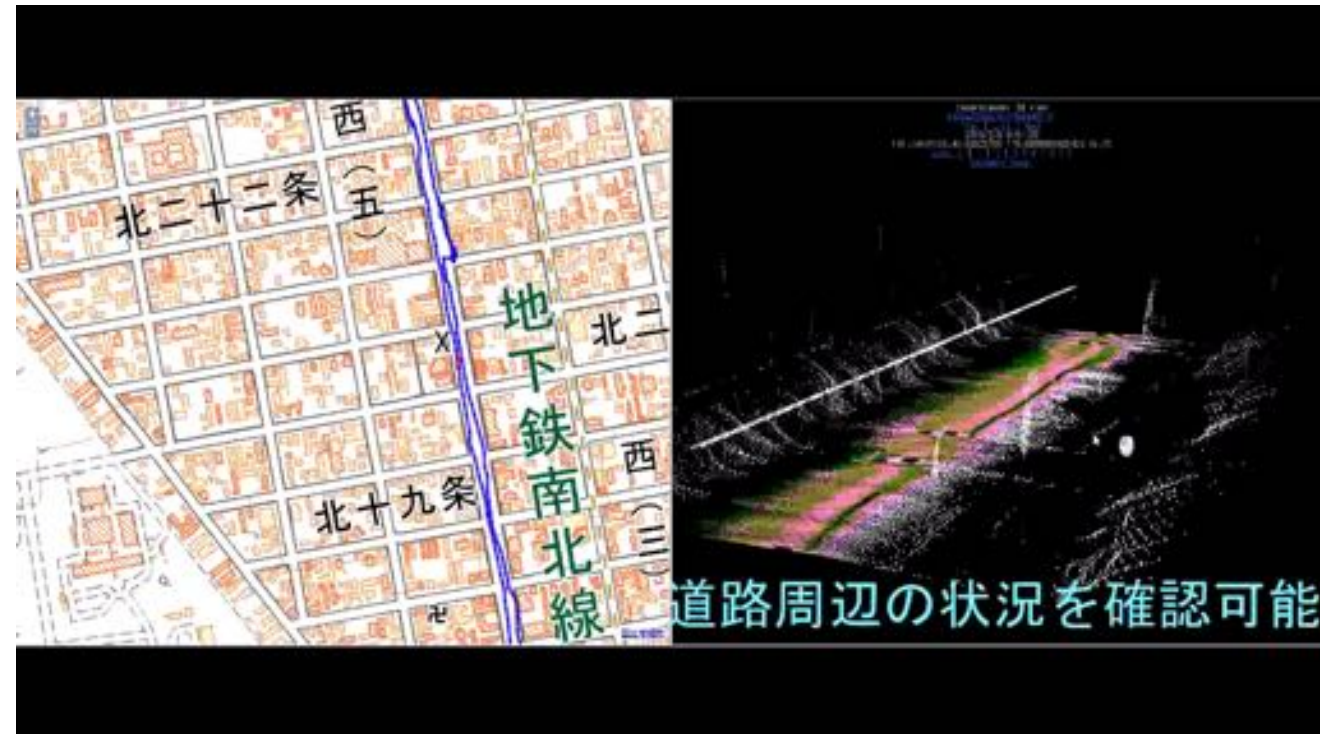


Overview of the system



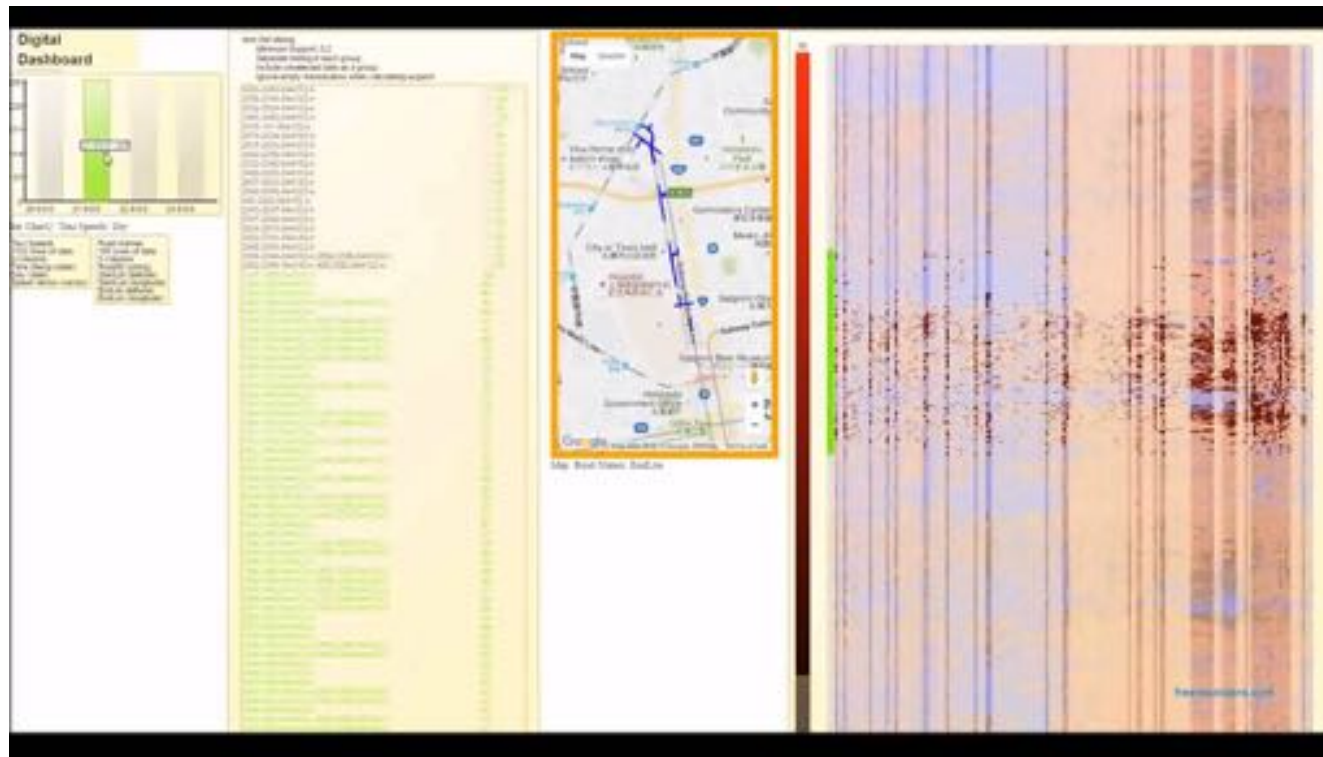
3D measurement of road snowfall by laser range scanner

Device attached to a bus



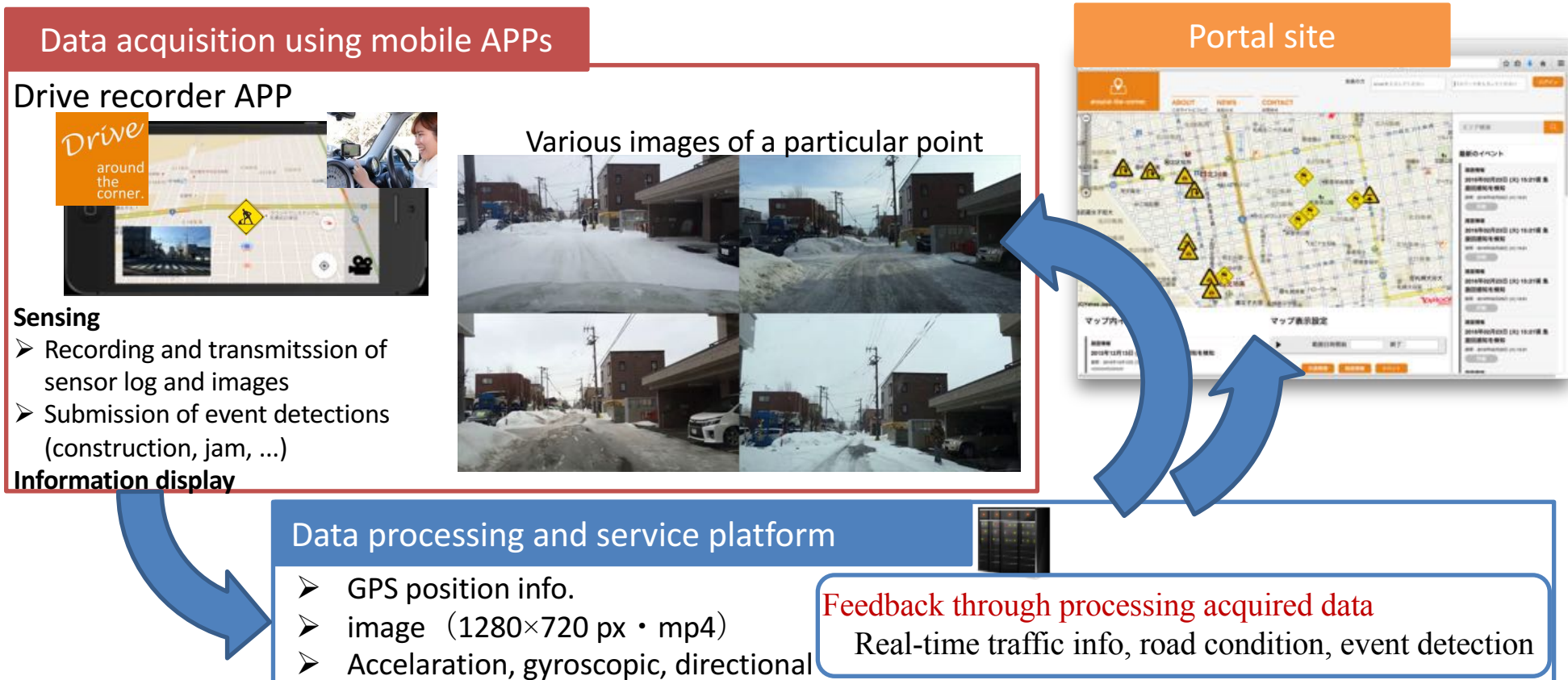
Measurement of road snowfall in cooperation with Sapporo city's snow control operations for important bus routes

Traffic jam analysis through Exploratory visualization and analytics

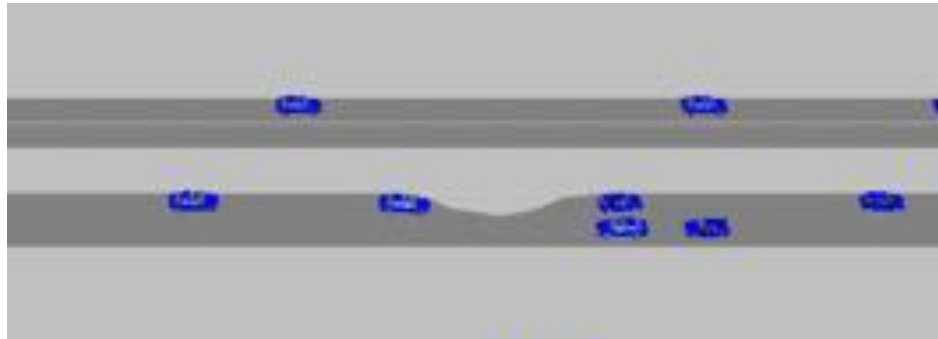


- Interactive analysis by improvisational combination of map and data mining library tools
- Evidence-based analysis of traffic jam causes
 - ⇒ Effective pinpoint snow removal

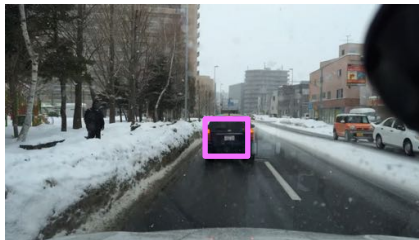
Measurement of road conditions using crowd-sourcing APPs for drive recorders



Simulation of snowfall effects to road traffic



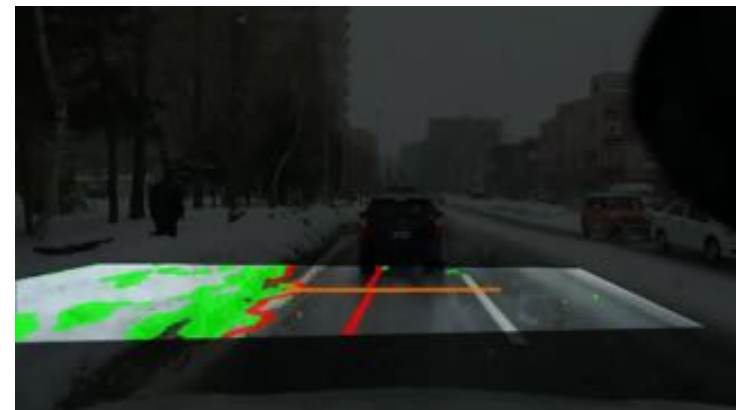
Measurement of effective road width by car-mounted cameras



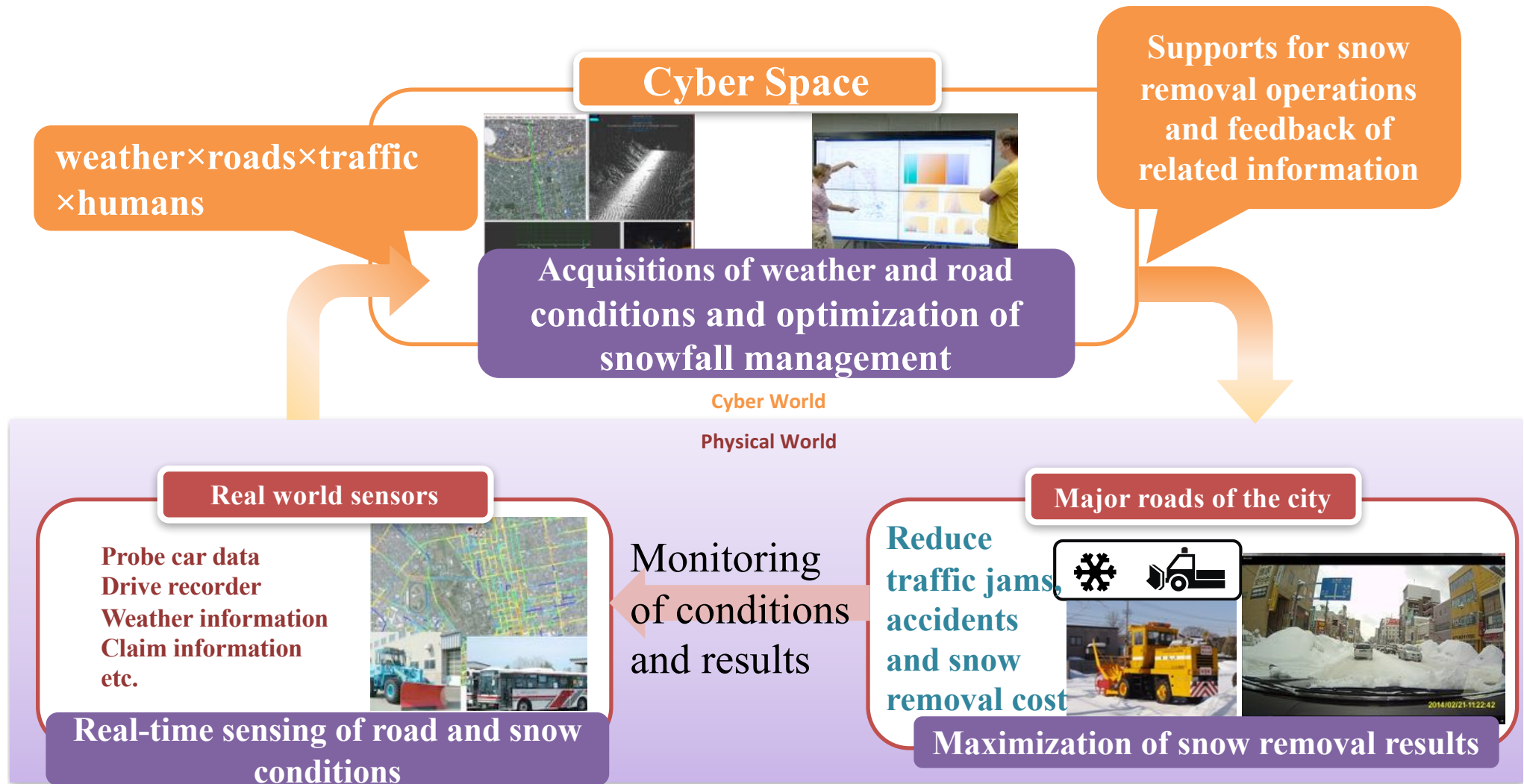
Vehicle detection



Obstacle detection



Summary of Evidence-based Improvement of Snow Removal in Sapporo



- **CPS data management**

- **Smart Federated Analytic Env**

Ongoing Demonstrative Subprojects

1. Smart Snow Removal Operations
2. **Productivity-based Energy Efficiency**

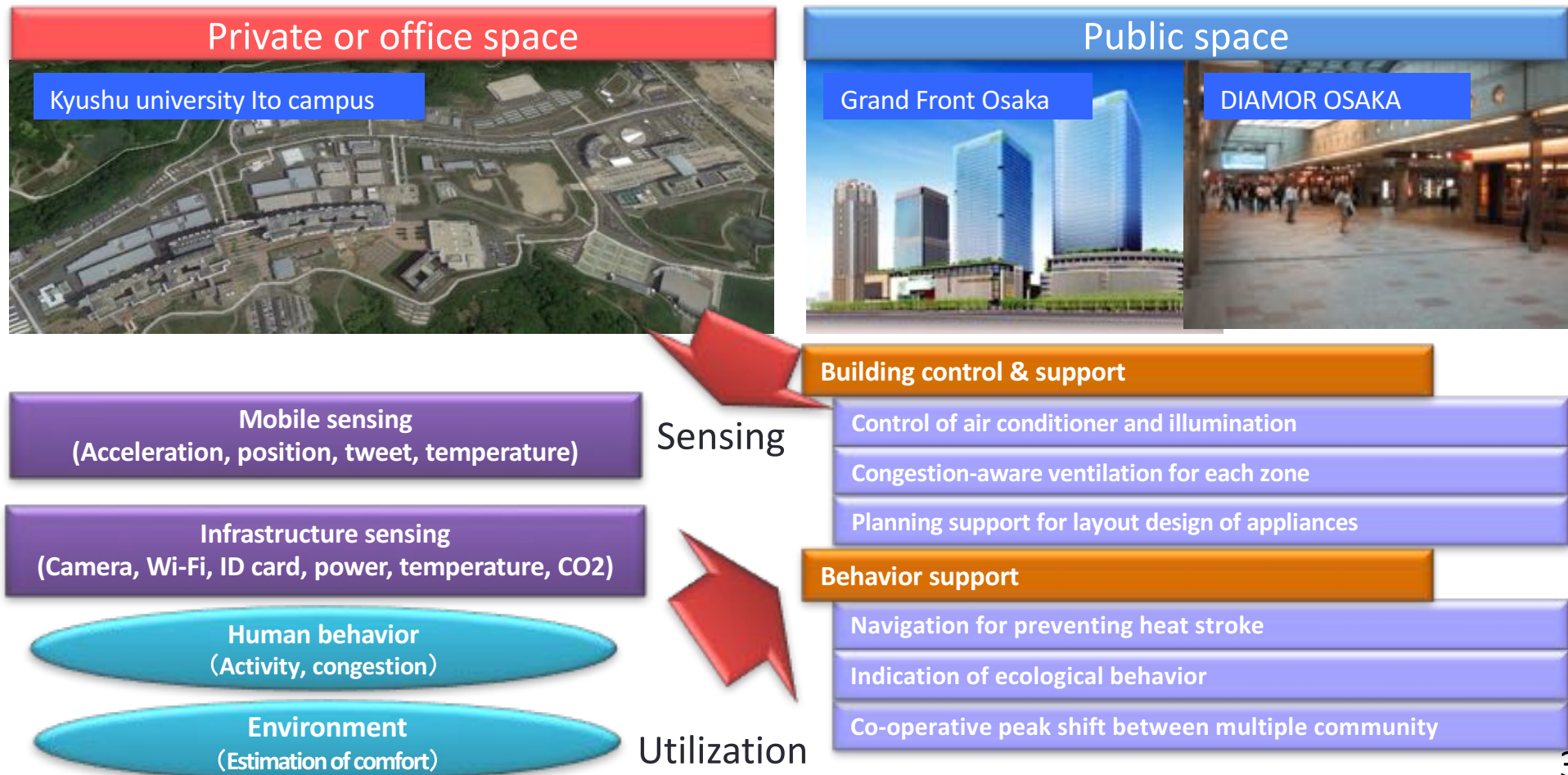
- **Pervasive Sensing**

- **Multi-stream data collection & analyses**

DEMO 2: Human centric Energy Management

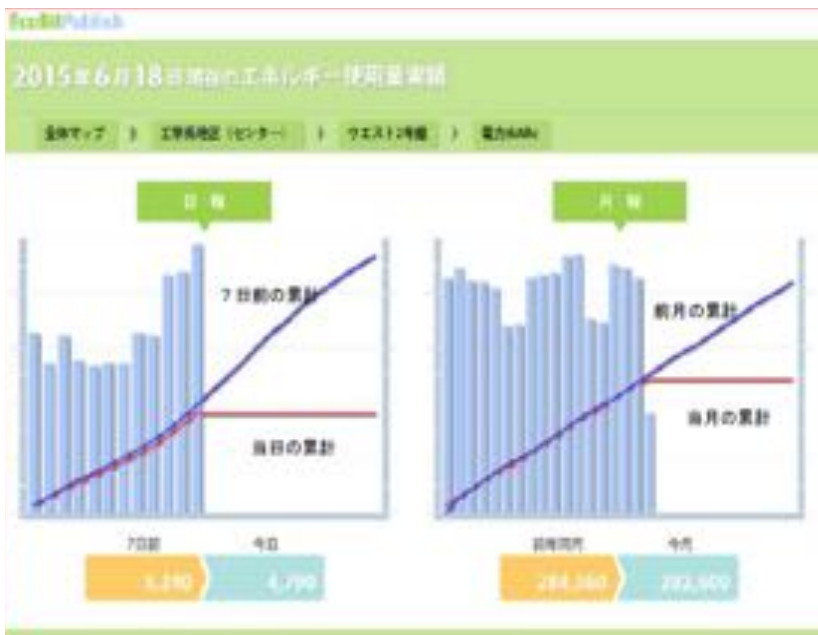
Productivity-based Energy Efficiency

- Energy per 'productivity' instead of the physical size
- Evaluation of 'comfort' as productivity



Conventional energy saving measures

- Coarse sensing



On a building and daily basis

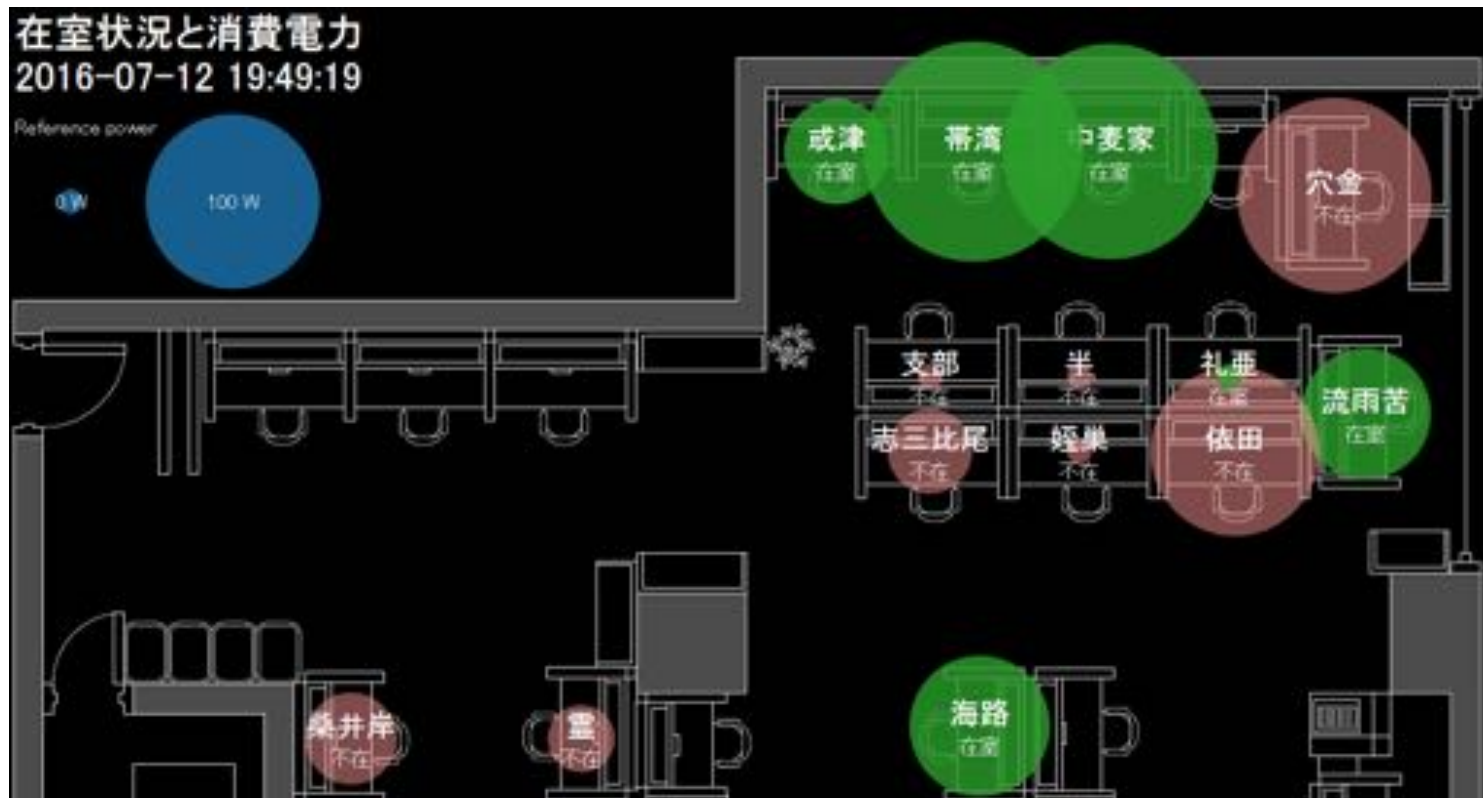
- Coarse feedback

The infographic provides three energy-saving tips with corresponding icons and text:

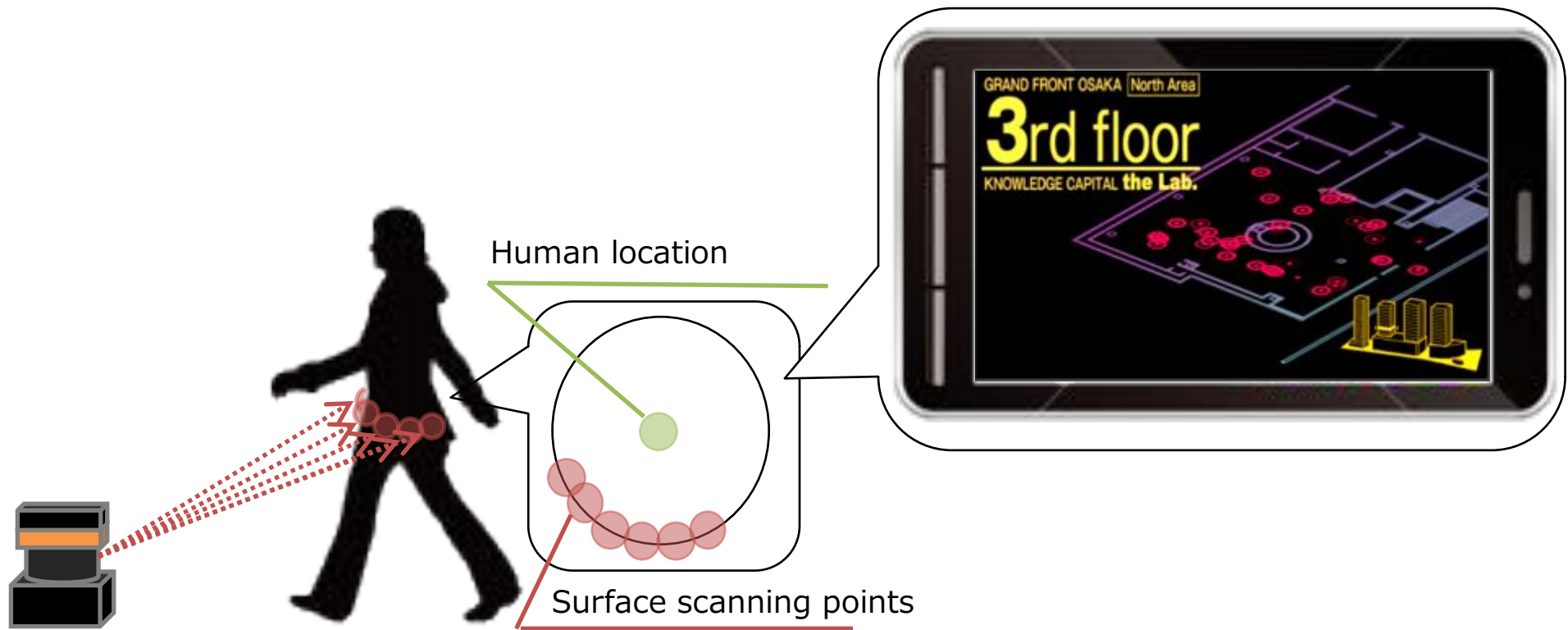
- Tip 1:** An icon of an air conditioner with '20°' above it. The text reads: 'エアコンの設定温度は夏27°C、冬20°Cを目安にしましょう。' (Set the air conditioner to 27°C in summer and 20°C in winter.)
- Tip 2:** An icon of a light bulb and a plant. The text reads: '昼間は外光を取り入れて、照明を部分点灯しましょう。' (Use natural light during the daytime and turn off lights that are not needed.)
- Tip 3:** An icon of a computer monitor and a power strip. The text reads: 'パソコン等の不要な電源はこまめに消し、帰宅時には不要なコンセントを抜きましょう。' (Turn off the computer when not in use and disconnect all plugs before going home.)

No use of acquired data, uniform directives

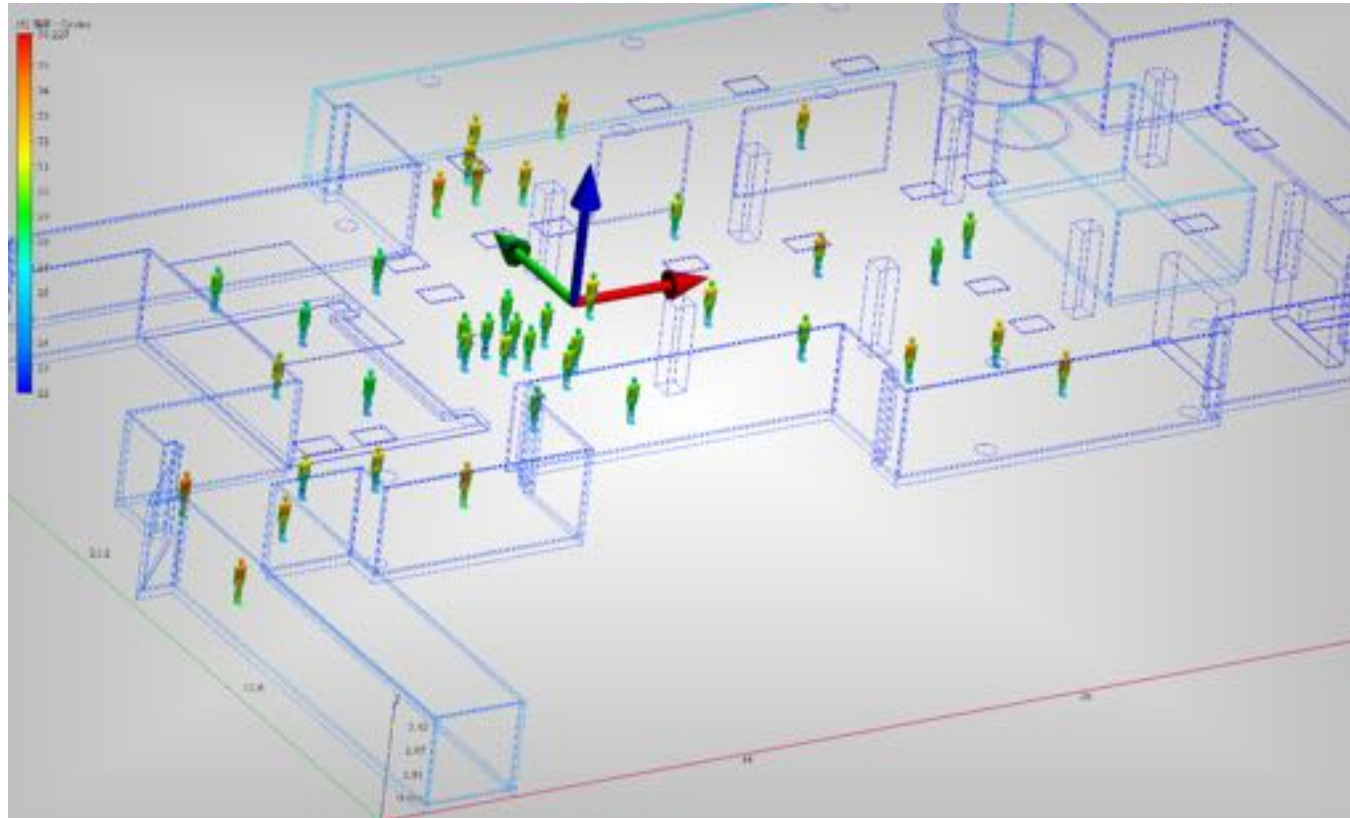
Power consumption measurement by individual power sensors



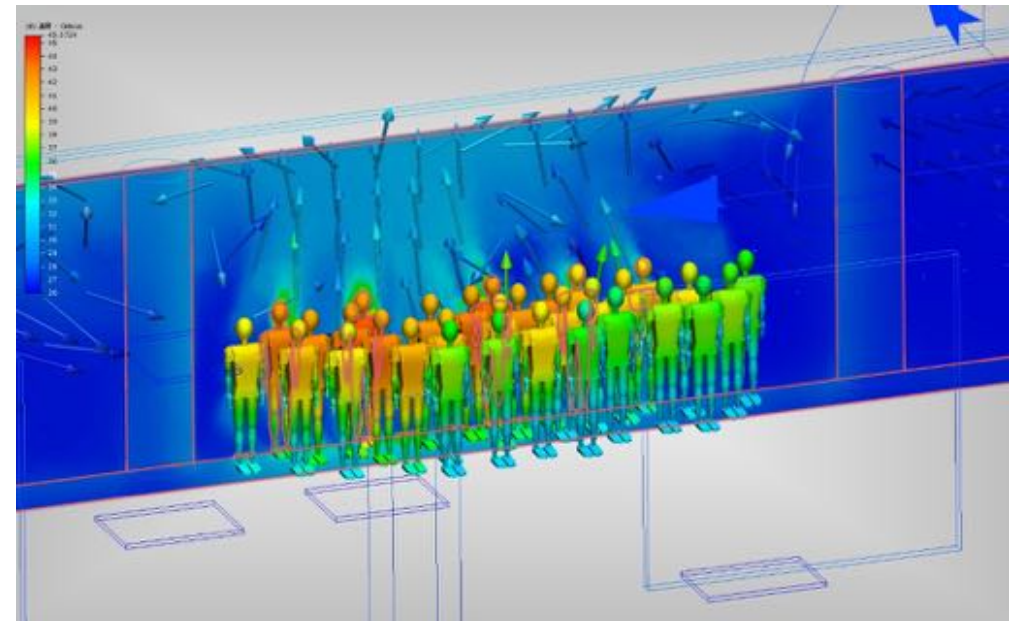
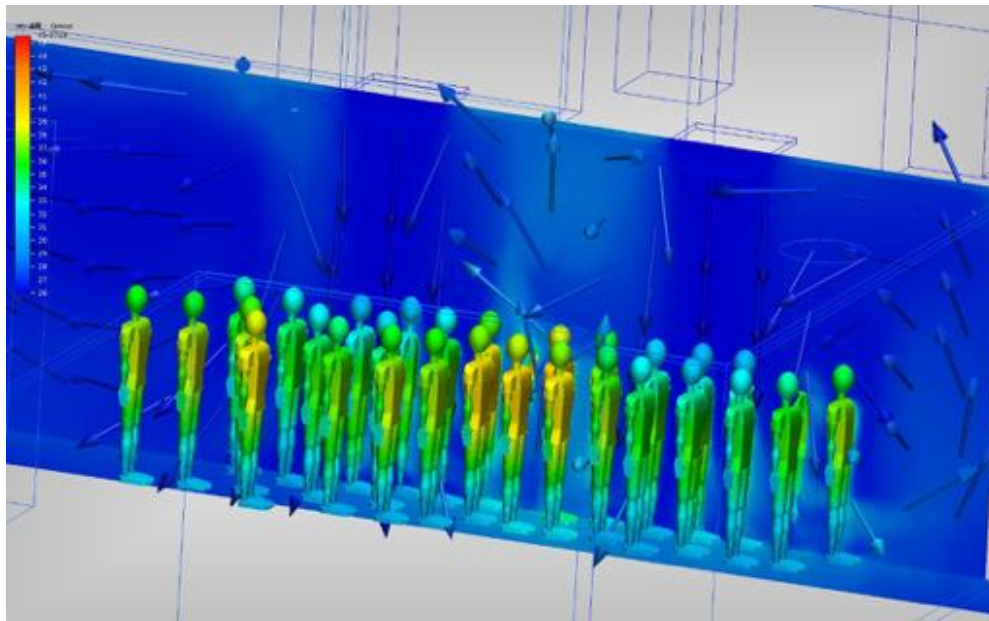
Human location sensing by laser range scanners



Sensor data integration in virtual environment



Comfort estimation model based on congestion and environmental data



Comfort control based on ambience of people and air flow

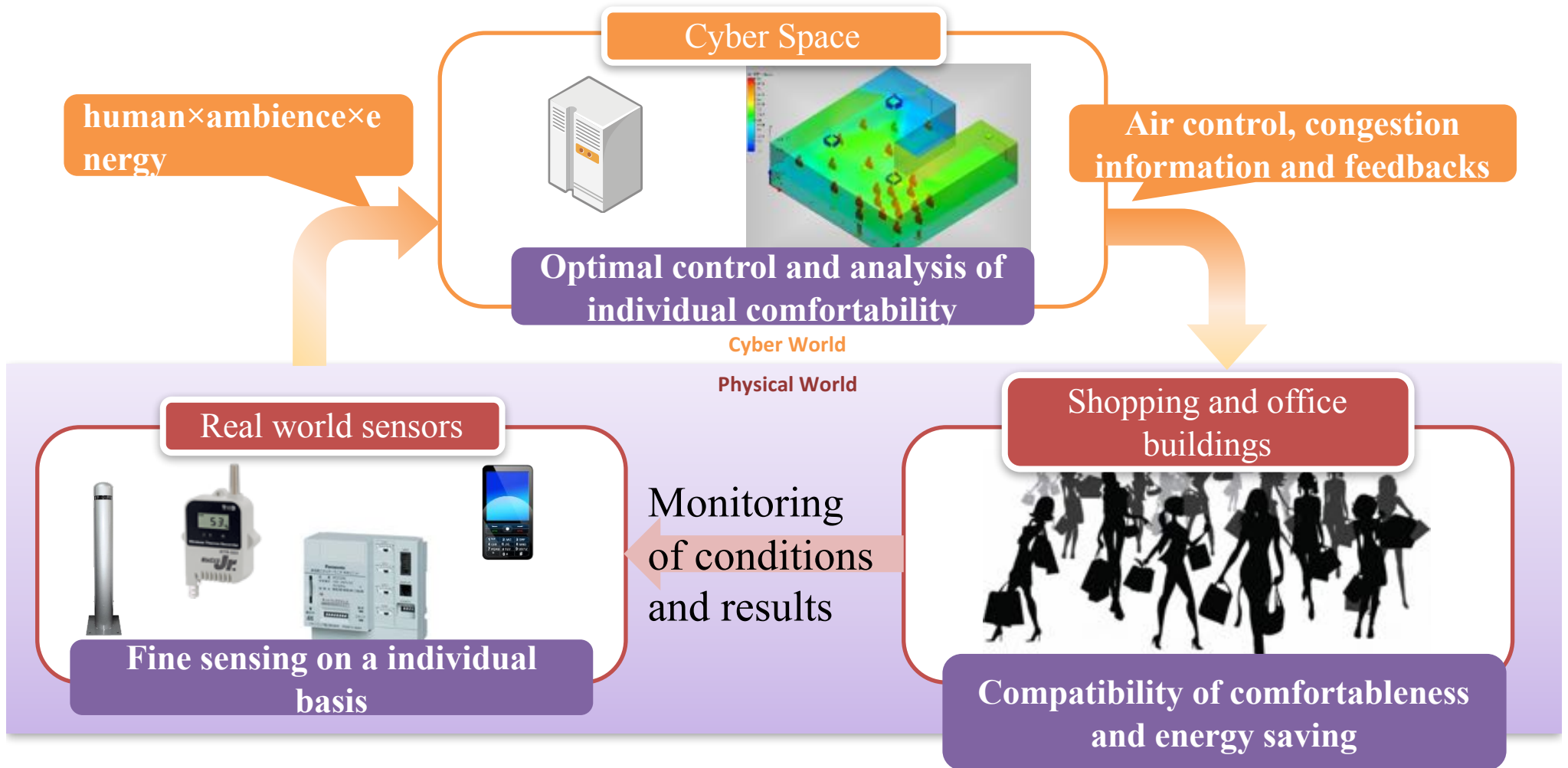
2 cases: smart campus & commercial building

Smart campus
experiment at
Kyushu University



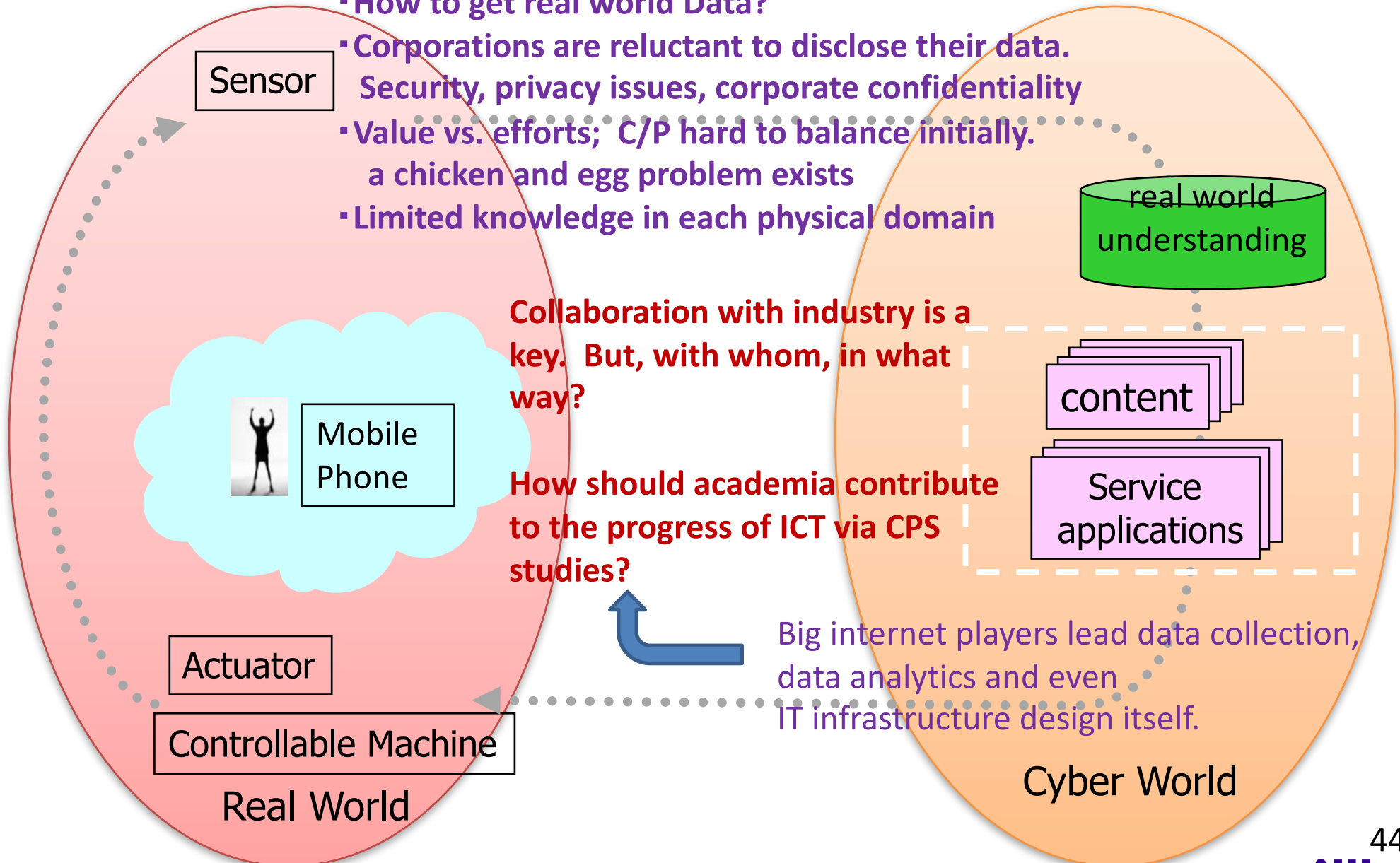
Experiment at
Knowledge Salon of
Gran Front Osaka by
Osaka University

BEMS2.0 Human centric BEMS compatible both with comfortableness and energy saving



Challenges in CSP Studies

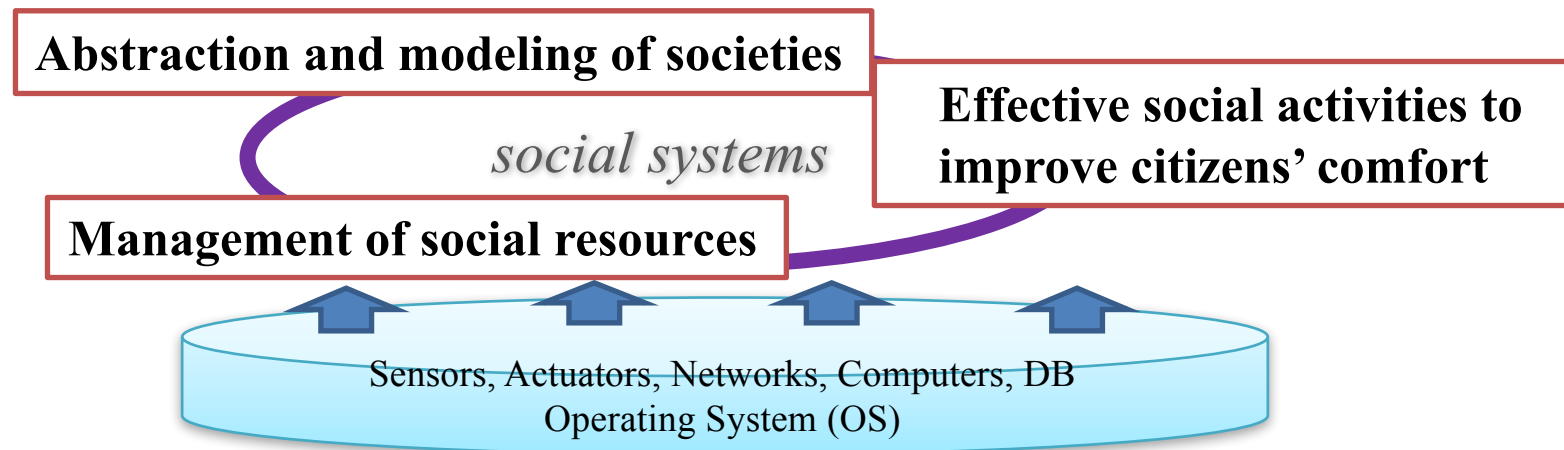
- How to get real world Data?
- Corporations are reluctant to disclose their data. Security, privacy issues, corporate confidentiality
- Value vs. efforts; C/P hard to balance initially. a chicken and egg problem exists
- Limited knowledge in each physical domain



Summing-up: CPS to “Scoal CPS”

Aiming at a new CPS concept that is applicable to change various social systems

Social CPS as an operating system of society



Social and human aspects are important in order to correspond to societal dynamics.