Start with Sensing Technologies for Fully Automated Farming and for Comprehensive Goals (SDGs)




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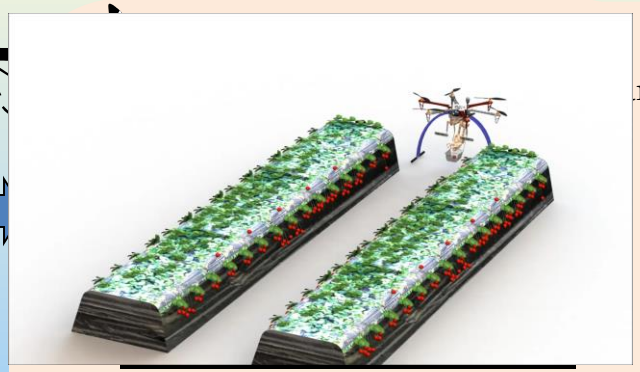
Information oriented field



Operation records
Sensing information

Farming guidance
DSS for farmers

Residue
rbonization

Fresh
Product

Information added product

Product

ID tags

Precision Agriculture

Information (IT) Agriculture with Sensors

(machines or robots are not indispensable but sensors)

Smart Agriculture

More Robots and More AI and IoT

BRAND

BRAND

marketing value

New flow of
product and information

By courtesy of Shibuya Seiki, John Deere, BRAIN, NARO

History of Agri-robot Researches

Agri-robot I (Since 1982)

Seedling production

- Adoption of industrial robots
- Investigation of robot mechanisms based on plant properties

Agri-robot II (Since 1992)

Fruit Harvesting

- Fusion between horticultural and engi… pproach
- Construction of fundamentals of relation "Human-Plant-Robot"

Not diffused yet

Agri-robot III (Since 2002)

Fruit Grading

- Precision Agriculture oriented robot
- Product information addition … tion, and utilizati

Robot based precise information

Agri-robot IV (Since 2013)

Drone, Wearable robot

- AI & IoT Based Smart Agriculture oriented robot
- Small cooperative distributed robot

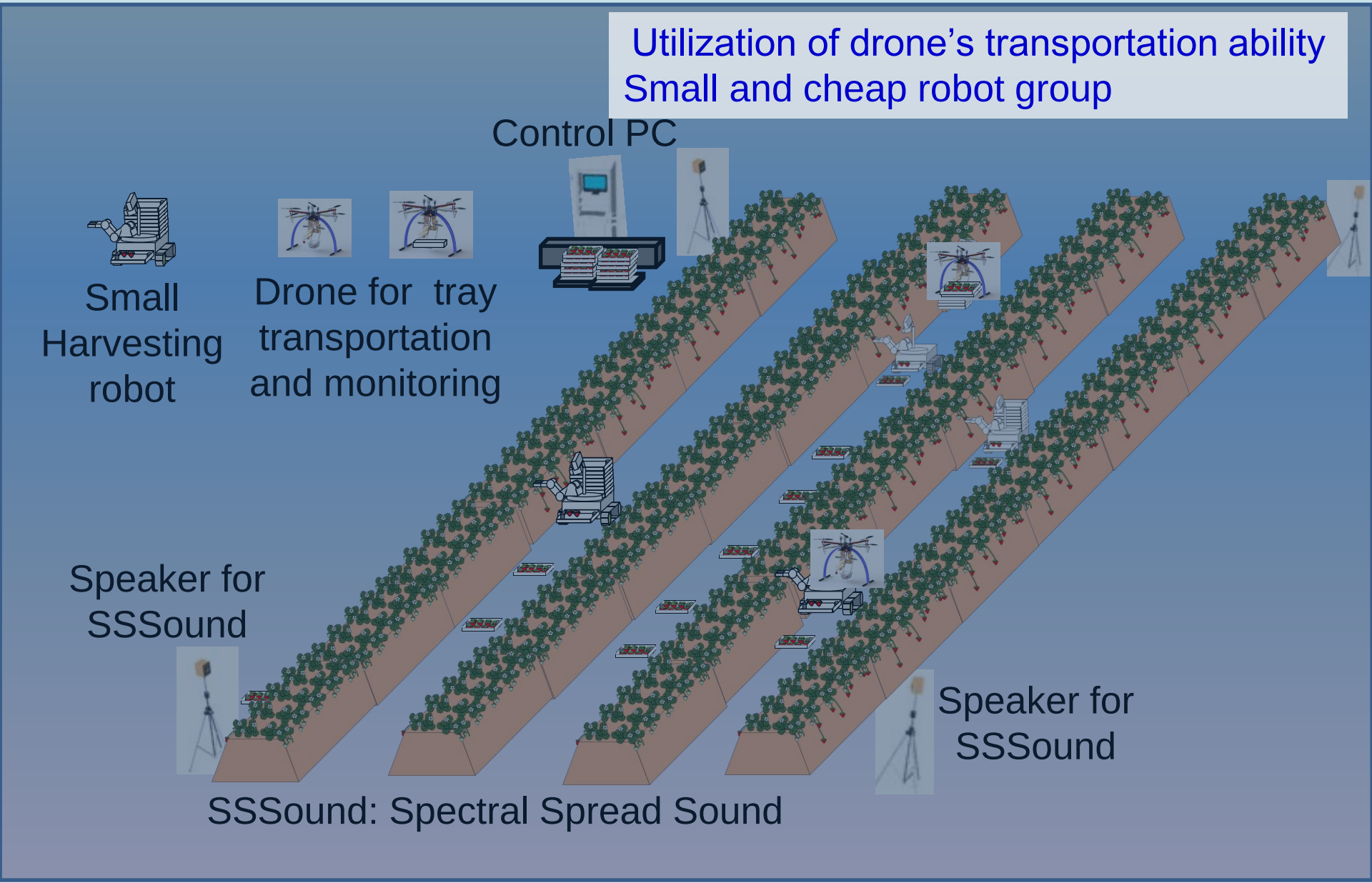
Agri-robot V (Since ???)

Micro insect robots???

By Kondo

Small distributed cooperative robots

Utilization of drone's transportation ability
Small and cheap robot group



Information flow in Smart Agriculture

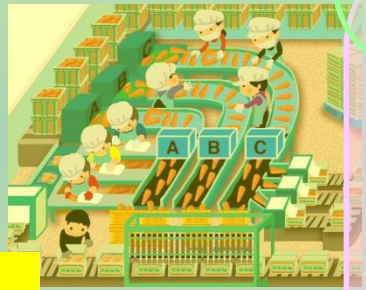
Producer

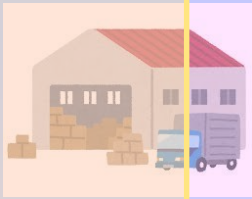
Farming Guidance

Consumer

Health

Food Safety &Security





Agriculture

Food

Field

Seedling

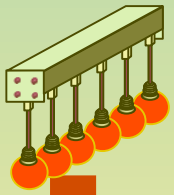
Grading

Storage

Pr

Pre-harvest

Post-harvest



More IoT based data acquisition by sensors & mining

Time series data, Spatial data & Overlaid data analysis with environmental conditions

Machine learning
Neuro
Multi-variate analysis
Deep learning

Roles of Grading Facility and Sensors

1. Efficient sorting, and **labor saving**
2. **Uniformization** of fruit quality
3. Enhancing **market value** of the products
   (Establishing **local region brand** of products
4. **Fair payment** to producers based
   not only on quantity but on quality of each fruit
5. **Farming guidance** from grading results
6. Contribution to the traceability system
   for **food safety and security**
7. **Saving the food loss**

1970s
Mechanization

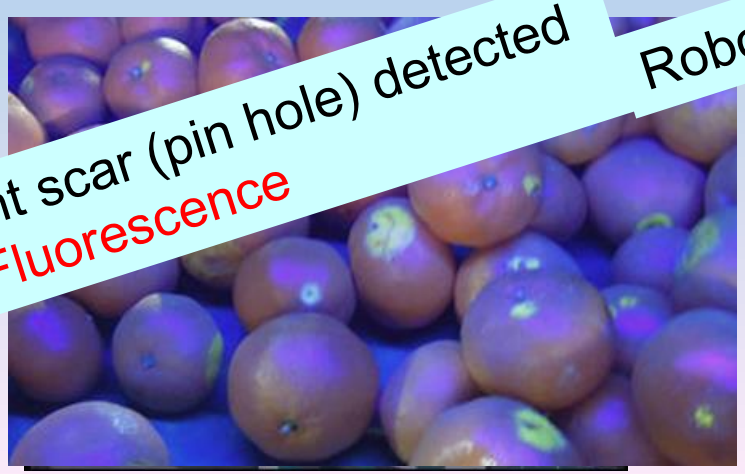
1990s
Non-destructive inspection

2000s
Informatization

2010s
Fluorescence

2020s
???
Health

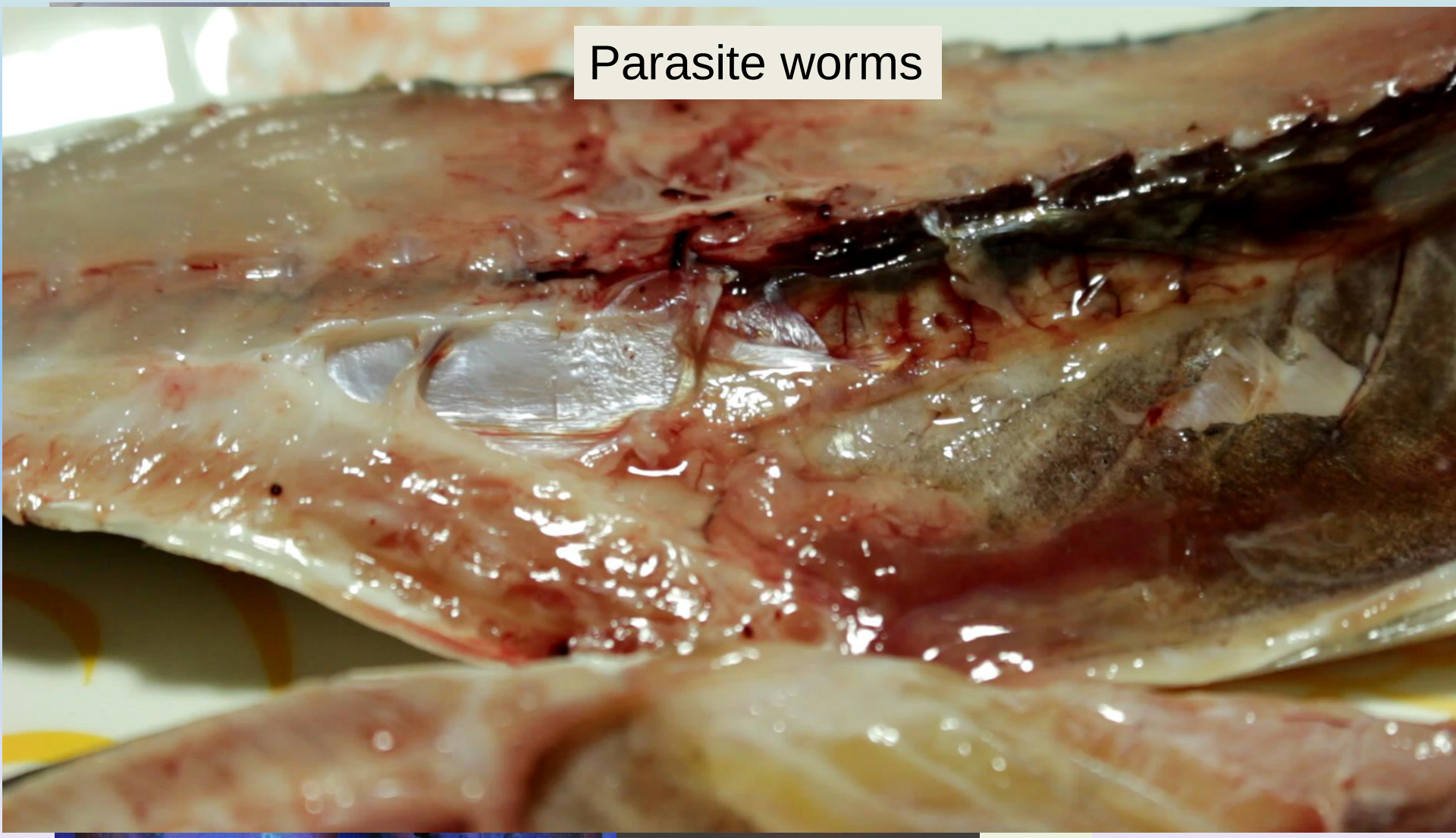
Slight scar (pin hole) detected by Fluorescence

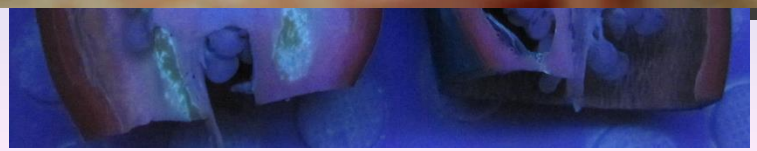


Robot based precise information

By Kondo

All Products are Fluorescence substance holders

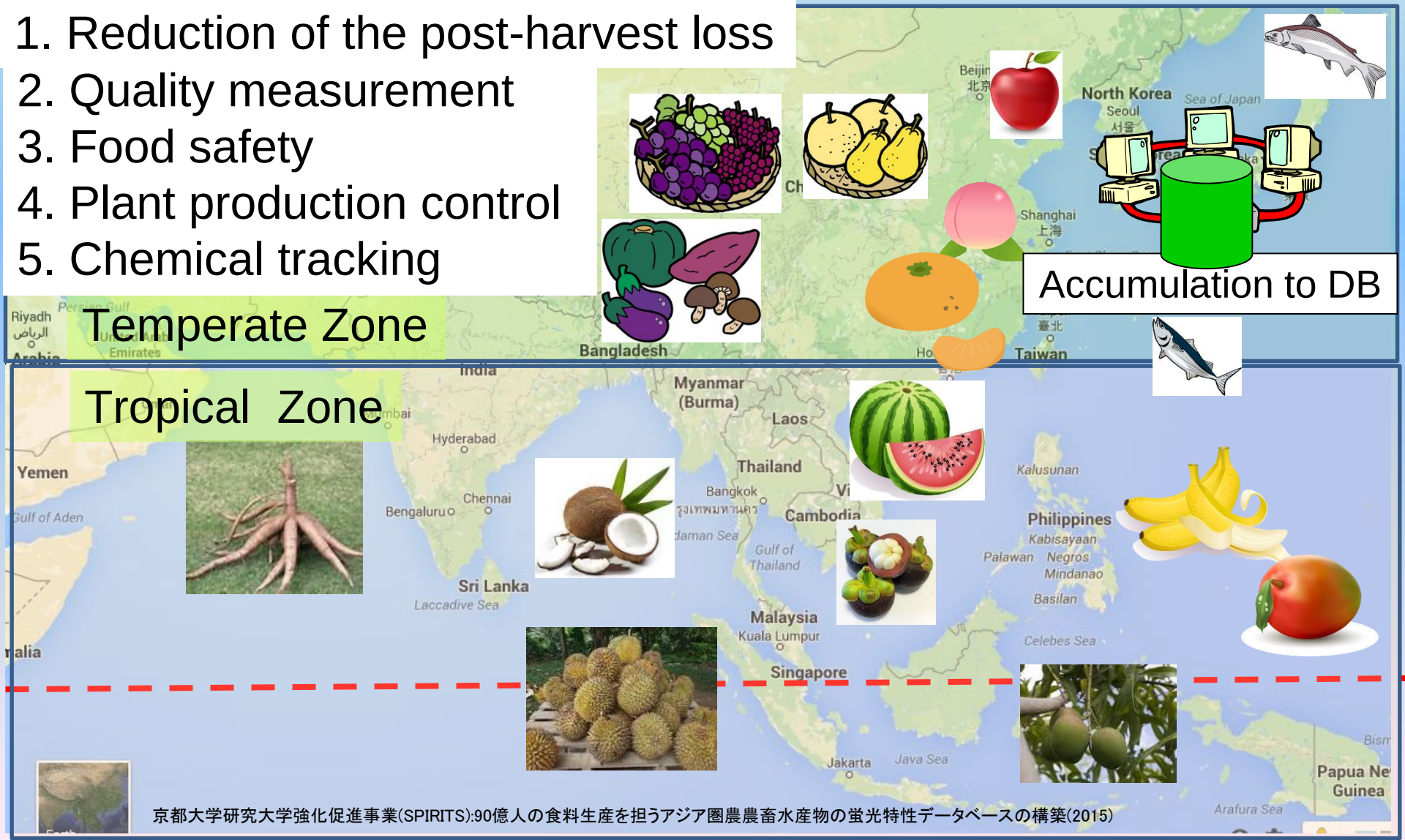




Fluorescence Database Construction Project

Agriculture, Livestock, Aquaculture, and Marine Products for 9 Billion People's Food Production

1. Reduction of the post-harvest loss
2. Quality measurement
3. Food safety
4. Plant production control
5. Chemical tracking



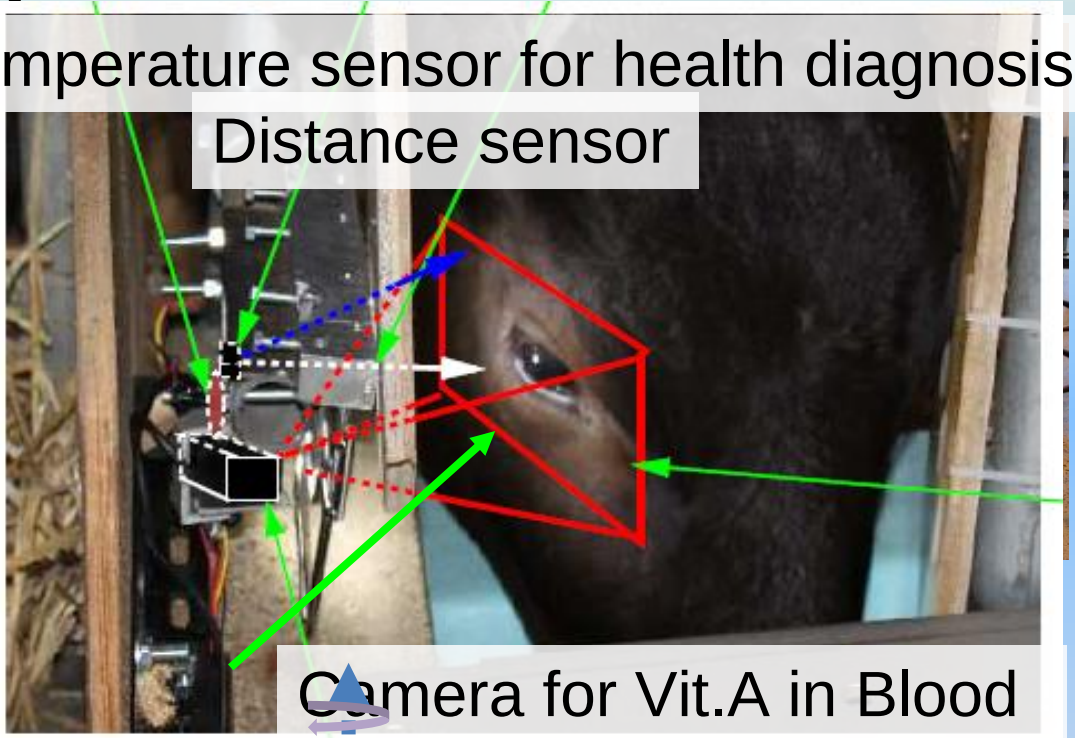
京都大学研究大学強化促進事業(SPIRITS):90億人の食料生産を担うアジア圏農農畜水産物の蛍光特性データベースの構築(2015)

Technologies in Livestock

Milking Robot

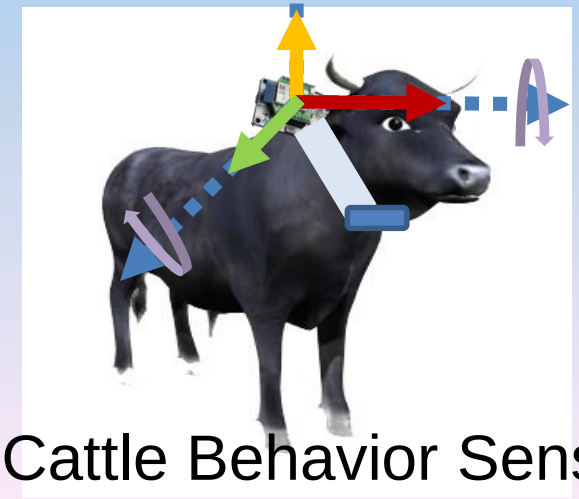
Temperature sensor for health diagnosis

Distance sensor



Camera for Vit.A in Blood

Wool Harvesting Robot

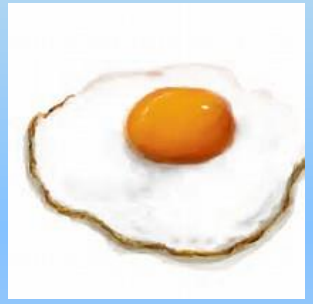


Cattle Behavior Sensor

近藤　直，門田充司，野口　伸：農業ロボット(II) ー機構と事例ー，コロナ社(2006)
Peng, Y., N. Kondo, T. Fujiura, T. Suzuki, Wulandari, H. Yoshioka, E. Itoyama. 2019. Classification of multiple cattle behavior patterns using a recurrent neural network with long short-term memory and inertial measurement units. *Computers and Electronics in Agriculture*, *157*, 247–253

Eggs and Chickens

- Table Egg (Infertile Egg)



Crack and blood inspection

- Fertile Egg → Hatch → Hen t… …male

If Male,

All Killed.
6 billion/year chicks

- …gg → Hatch → Broiler (3 kg)

Male

Female

Growth period: 45 - 48 days

50 -53 days

Necessity to discriminate gender

Economic loss
&
Ethical issues

https://www.nabel.co.jp/products/abd/

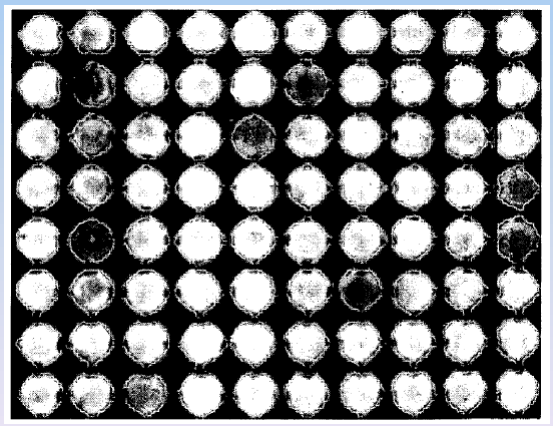
M. R. N. Bruijnis et al., J. Agric. Environ. Ethics, vol. 28, no. 5, pp. 939–960 Oct. 2015

[4]http://www.animalethics.org.uk/i-ch7-2-chickens.html

Key technologies of Individual Egg Measurement for gender discrimination and hatching window management

1) Egg shell temperature for predicting hatching time
   By Thermo camera (FIR) in the incubator
2) Spectral transmittance (Day 4) for chick's health diagnosis
   By Spectroscopy (NIR)
3) Heart beat for control hatching time
   By Photo interrupter (NIR)
4) Shell thickness for calcium consumption rate
   By Terahertz spectroscopy (THz)

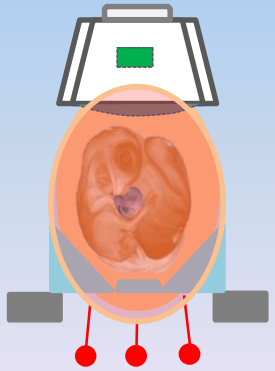
Precision livestock based on animal welfare



Temperature measurement

Transmissive light analysis

Photo interrupter



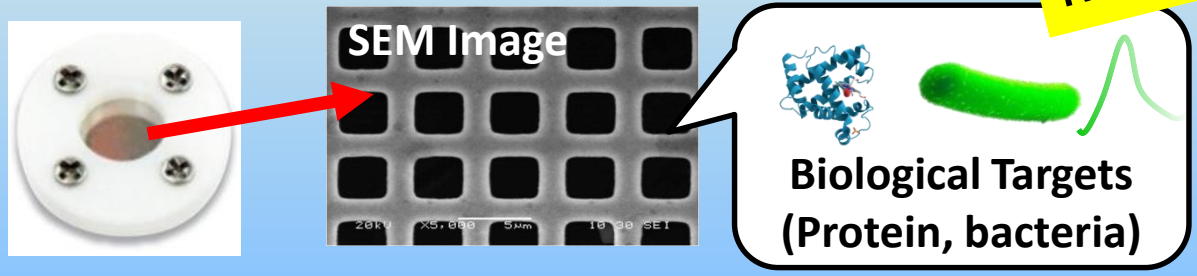
Heat beat count

Alin Khaliduzzaman, Naoshi Kondo, Ayuko Kashimori, Shinichi Fujitani, Tetsuhito Suzuki, Yuichi Ogawa: Non-invasive Detection of Chick Embryo Gender Based on Body Motility and a Near-infrared Sensor, EAEF_260 (2019)

Metallic Mesh Sensor for Detecting Biological Targets

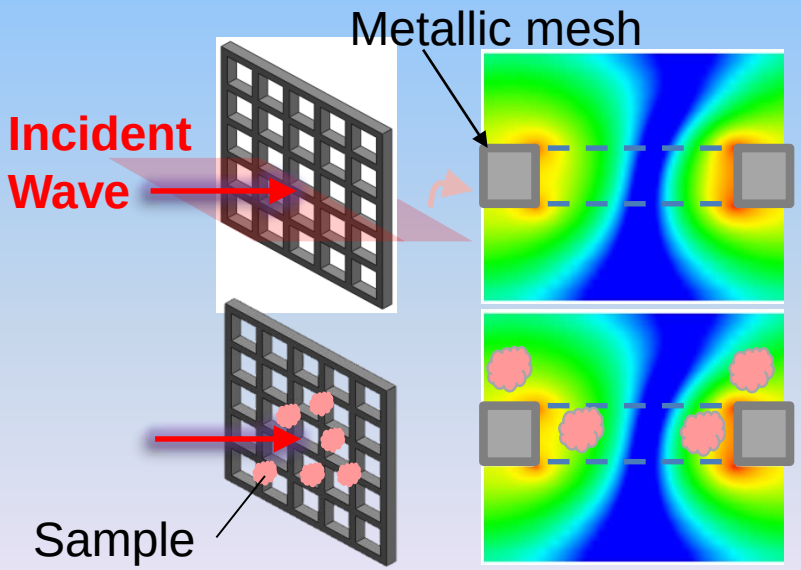
Metallic mesh Thin metallic film with periodic holes

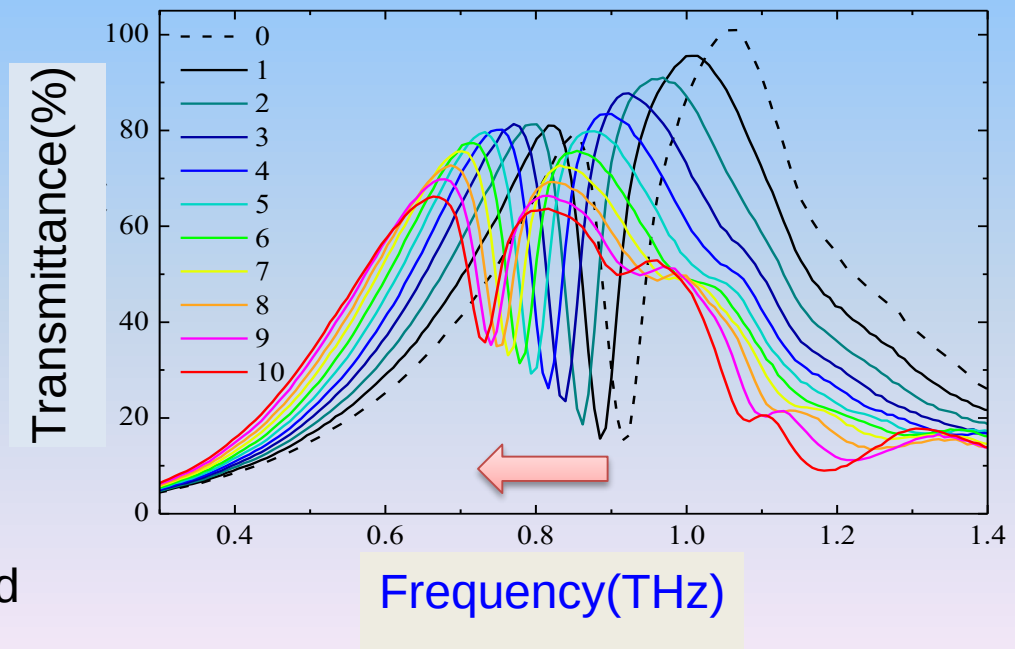
Microscale



Increase of refractive index shifts the spectra to lower frequency.

→ Works as a rapid & easy sensor

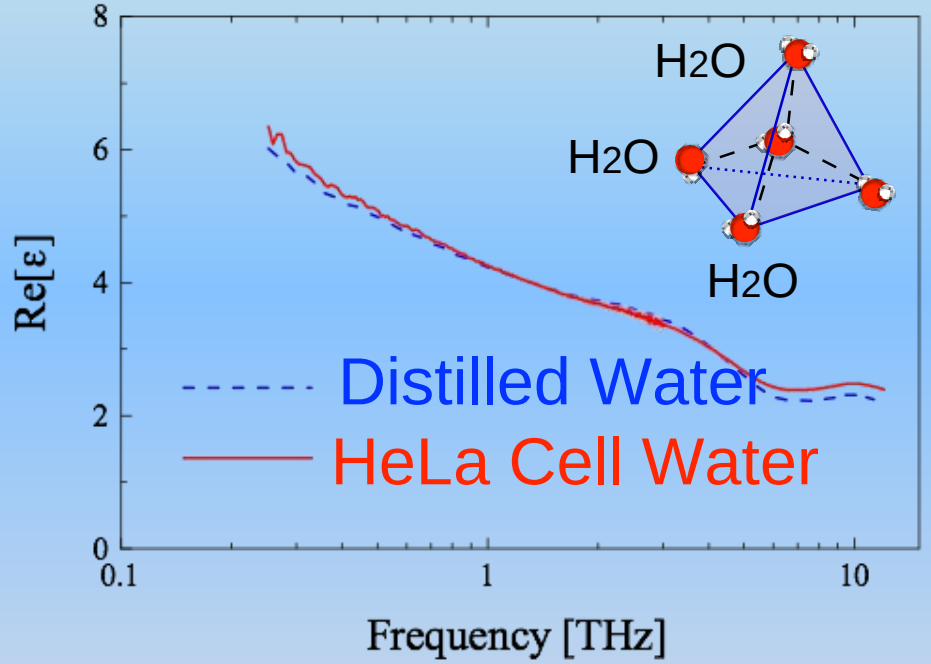


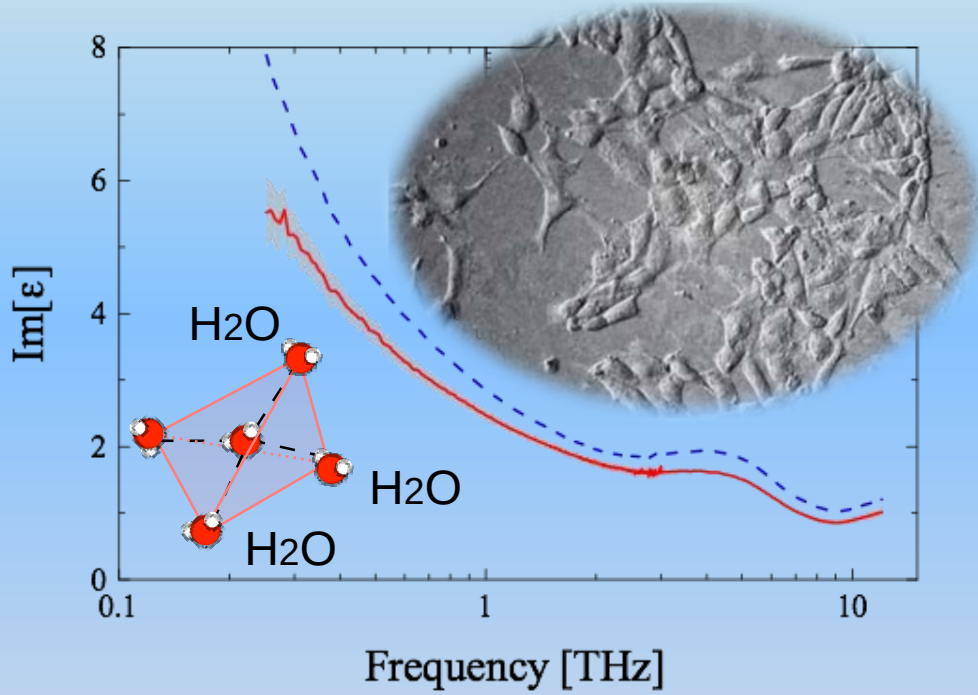


T. Suzuki et al, *4th IFAC Conference on Modelling and Control in Agriculture, Horticulture and Post Harvest Industry*, **4** (1), 327-330 (2013)

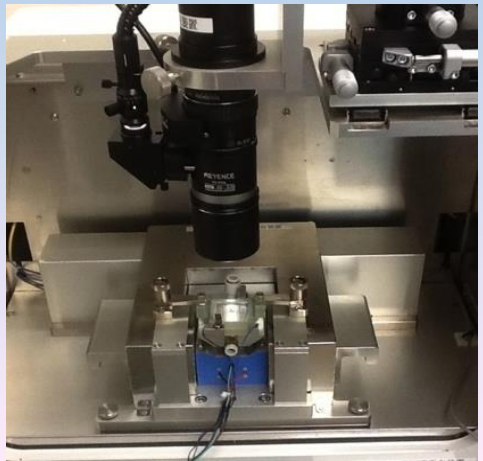
Complex dielectric constant of water & living cell (HeLa)

THz spectroscopy: intracellular water behaviors



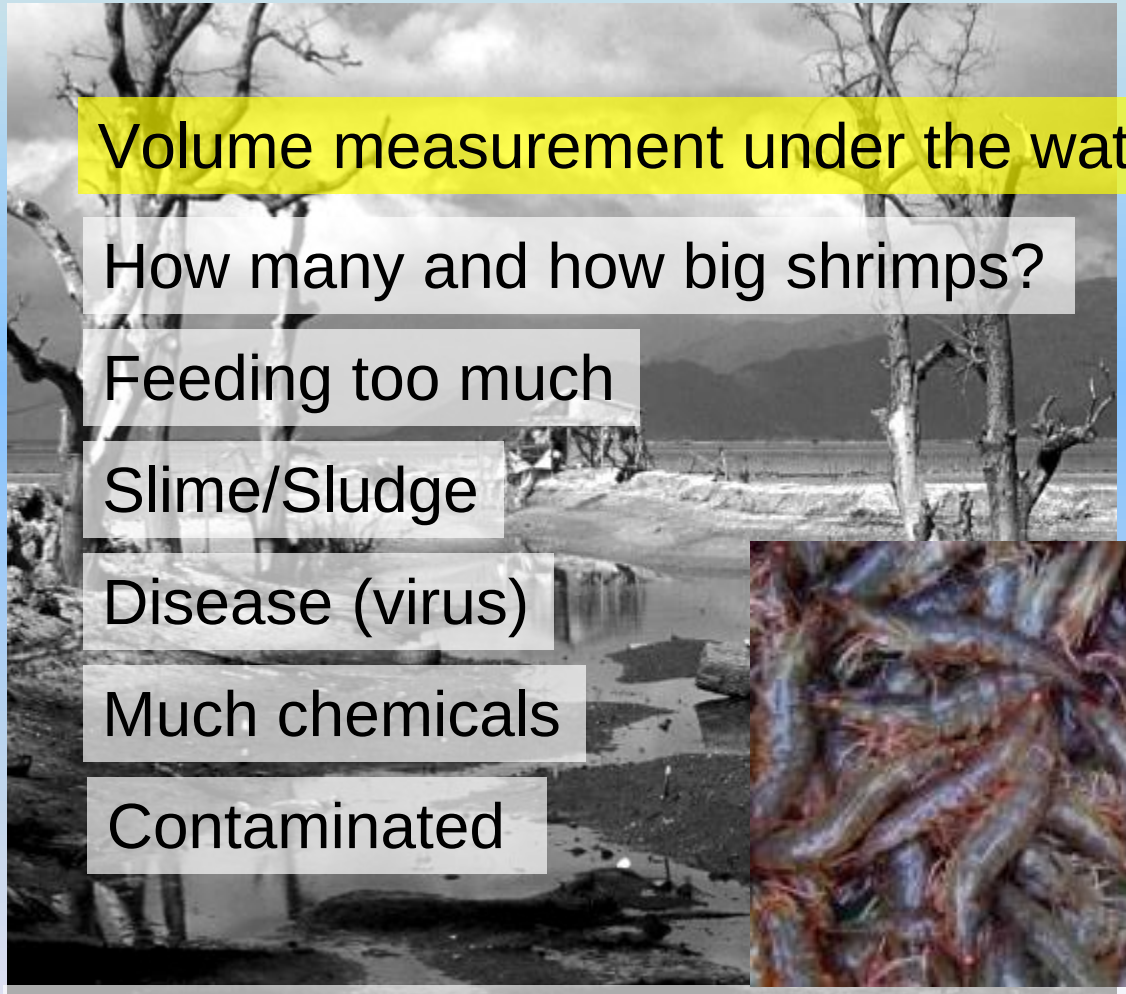


Hydrogen-bond inside cells is less stable than pure water.
20 % of intracellular water is hydrated to biomolecules.



K. Shiraga, Y. Ogawa, T. Suzuki, N. Kondo, A. Irisawa, M. Imamura," Characterization of Dielectric Responses of Human Cancer Cells in the Terahertz Region," Journal of Infrared, Millimeter, and Terahertz Waves, 35(5), 493-502(2014)

Aquaculture (Shrimp ponds)



Volume measurement under the water is necessary

How many and how big shrimps?

Feeding too much

Slime/Sludge

Disease (virus)

Much chemicals

Contaminated

Healthy

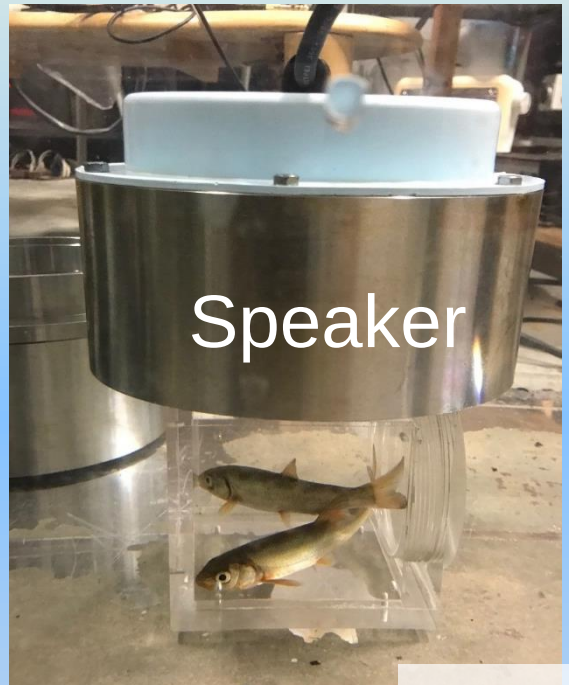
Virus affected

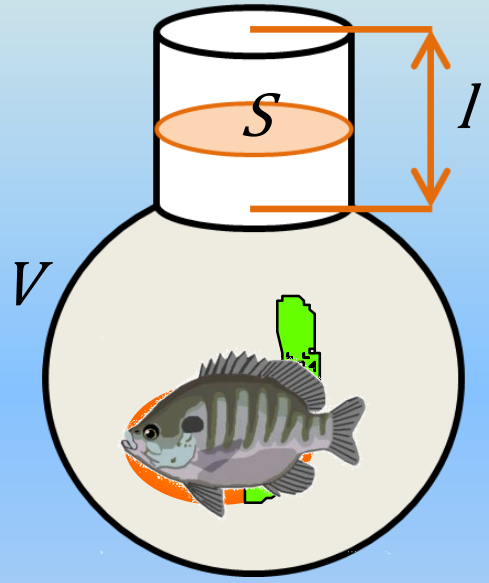
China, Thailand, Indonesia, Vietnam, Malaysia

http://www.thesalon.jp/themagazine/social/post-11.html

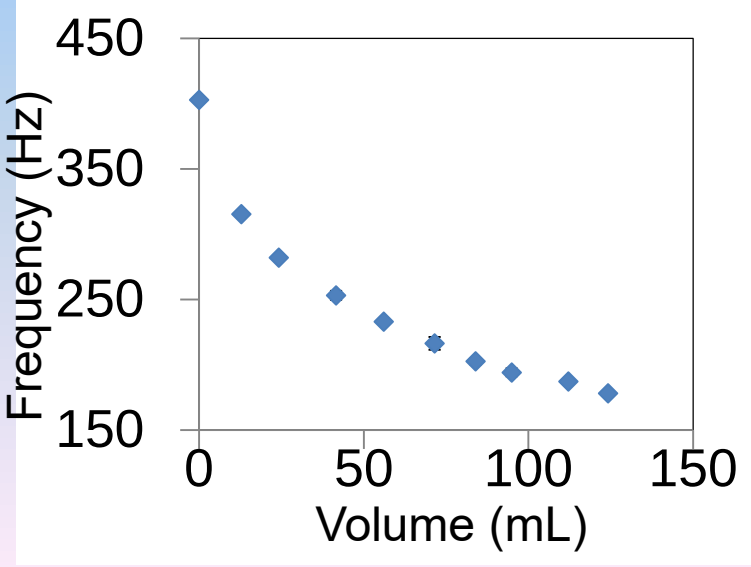
https://www.jica.go.jp/topics/news/2014/20140723_01.html

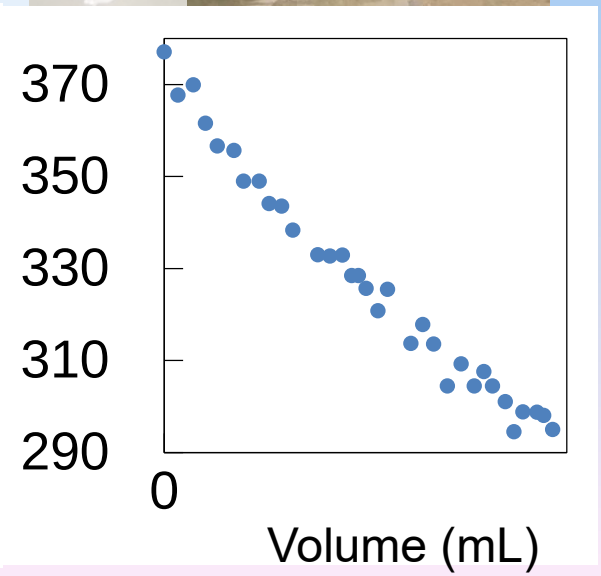
Fish Volume Measurement with Helmholtz Resonance





Resonator





l [m]: Neck length

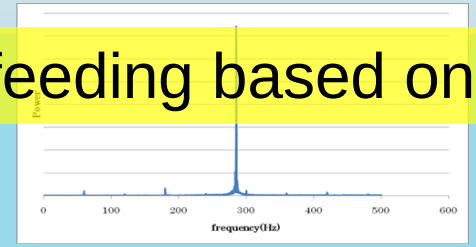
S [m^2]: Area of neck

V, V_0 [m^3]: Volume

f, f_0 [Hz]: Frequency

Fish Sorting by Volume Using Helmholtz Resonance

More precise feeding based on the fish volume



Peak Frequency

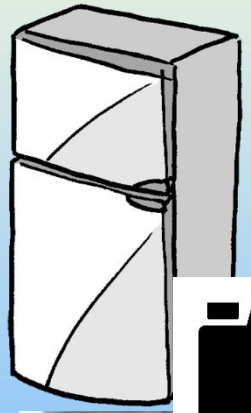
Large

Resonator

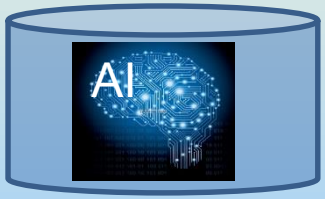
Small

$$V_0 = \left\{1 - \left(\frac{f_0}{f}\right)^2\right\} V$$

S. N. Njane, Y. Ogawa, T. Suzuki, K. Ogata, Y. Shinohara, T. Kawamura, T. Nishizu and N. Kondo, "Underwater Helmholtz resonator with double cavities for volumetric estimation of aquatic samples" Journal of Japanese Society of Agricultural Machinery and Food Engineers, 81(4): 233-242(2019.7)

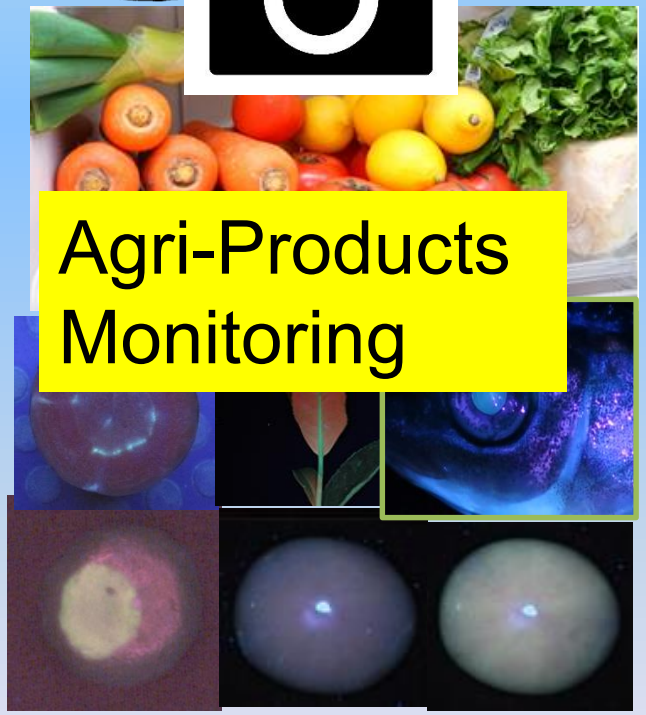


Fluorescence
Image processing
AI, IoT

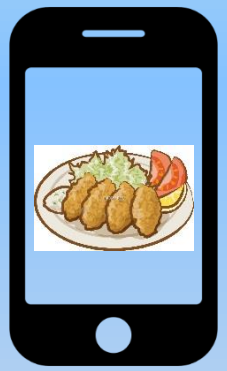


Shopping

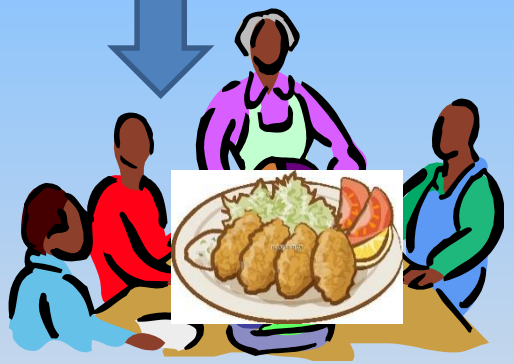
Consumption
before spoiled



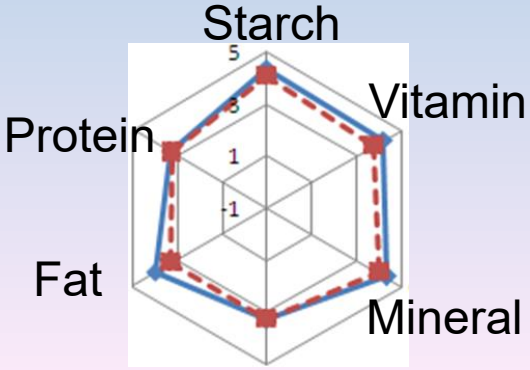
Agri-Products
Monitoring



Food



Today's Menu
Recommendation



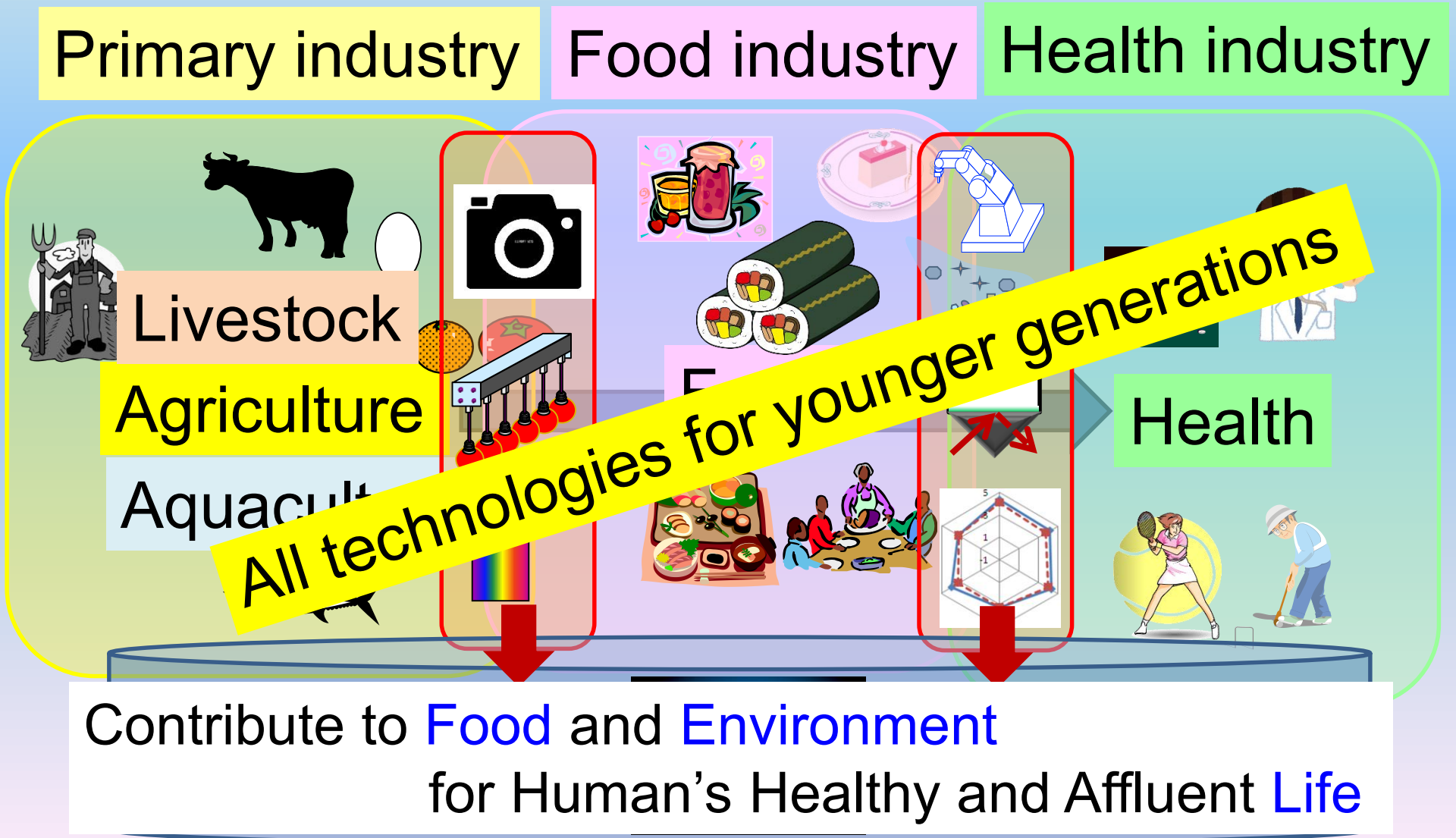
Health

Nutrition
Balance for family

Freshness & Safety

Which one should be consumed earlier and be removed (washed) carefully?

Conclusion: Start with Sensing Technologies for Full Automation and Comprehensive Goals



Contribute to Food and Environment
for Human's Healthy and Affluent Life