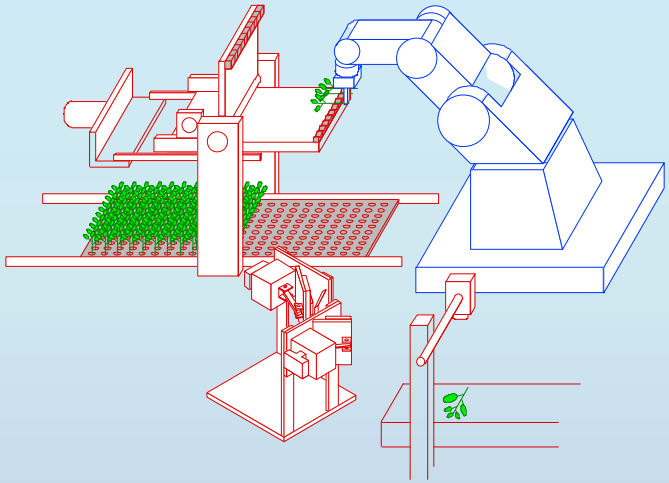
# Horticulture Meets Automation in the Plant Factory
## -- Robotization in Plant production --



***Naoshi Kondo***

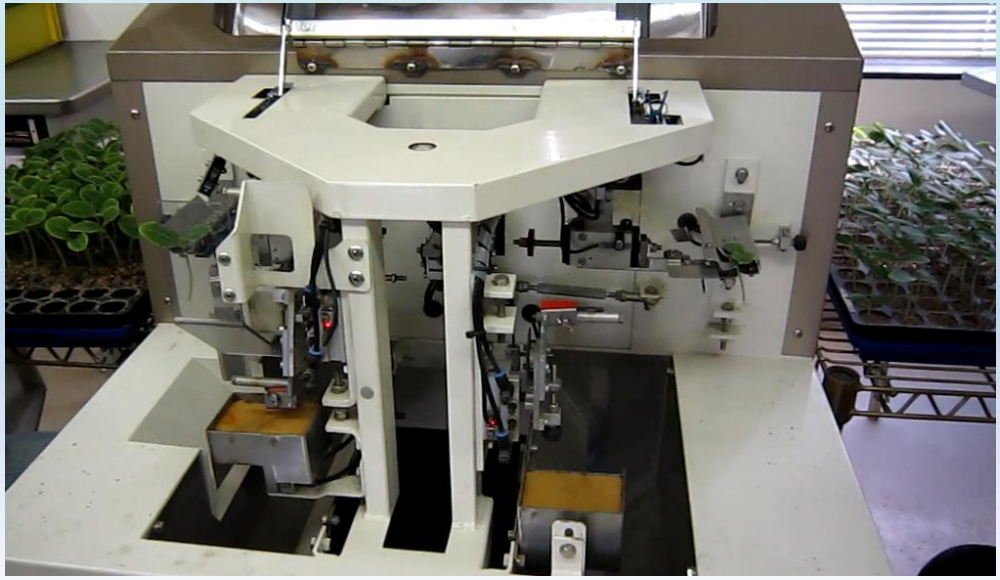
Laboratory of Bio-Sensing Engineering
Graduate School of Agriculture
Kyoto University, Japan

# The most desirable operation for automation

| (Operation) | (Commercialized robot) |
| --- | --- |
| Seedling production | Transplanting robot<br>Grafting robot<br>Cutting sticking robot |
| Plant management | Robotic sprayer |
| **Harvesting** | |
| Pre-Processing | Pre-processing machines for fruits and vegetables |
| Grading and Packing | Fruit grading robot system |

# Seedling production

Transplanting robot
(Visser, Netherland)



Grafting robot (BRAIN)

# Plant factory and Greenhouse

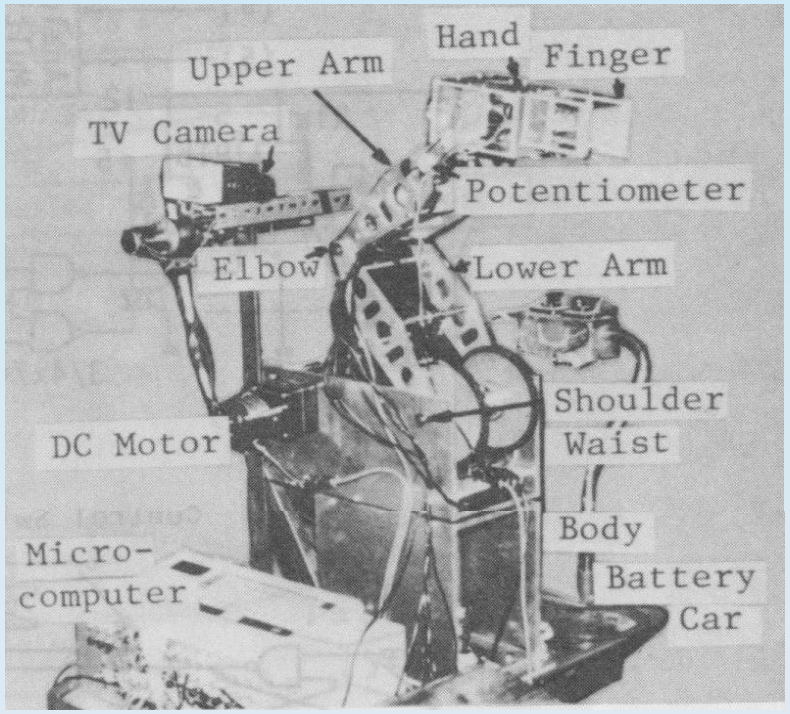
Fully Automated Plant Factory

(Kyushu Electric Power Co., Ltd.)

# The First Fruit Harvesting Robot

was developed in 1982 by Kawamura et al.,
at Kyoto University.

The tomato harvesting robot
consisted of
a **5 DOF manipulator**
a **harvesting end-effector**
a **stereovision** (color camera)
a **travelling device** (battery car).




The tomato harvesting robot

Following the robot, robotic technologies were applied to
cherry tomato, strawberry, cucumber, eggplant, cabbage, mushroom,
orange, apple, grape, melon, watermelon, asparagus and etc.

# Fruit harvesting robots in greenhouse

Cherry Tomato (Osaka Pref. U)

Cucumber (IMAG, Wageningen)

Tomato (Okayama U)


Lettuce (Shimane U)

Many robots were developed in 1980-1990s


Mushroom harvesting robot (Silsoe, UK)

Individual leaf harvesting is difficult.

# Perilla Leaf Production on Table Top Culture

# Difficulties on commercializing harvesting robot

1) Slow operation speed (1/3 or less)
2) Expensive cost (3 times or more)
3) Necessity of changing plant training system and cultivation method (Systematization of production)

⟶ Not commercialized yet so far

**+ Information from robot's sensors**

3D location of product, Harvesting time & date
Crop ID, Fruit Size, Color, Defects

# Perilla Leaf Sorting Robot System

(Shibuya Seiki Co., Ltd.)

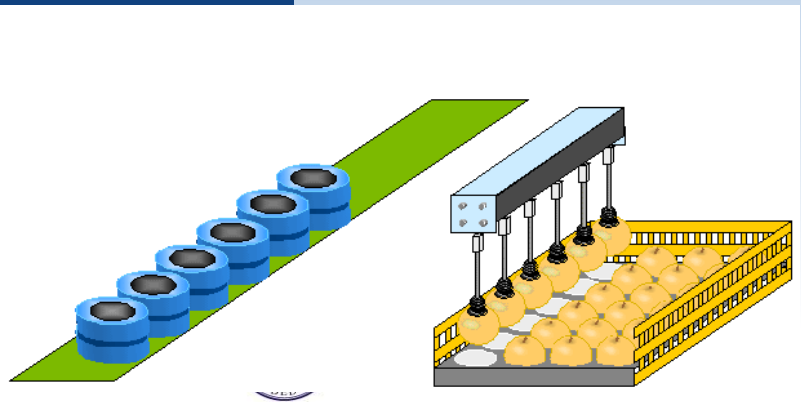
# Grading and Packing

Managing operation

(Sera-Saien)

Grading and Packing System in Tomato Greenhouse

# Fruit Grading Robot System with Traceability (Shibuya Seiki Co., Ltd.)



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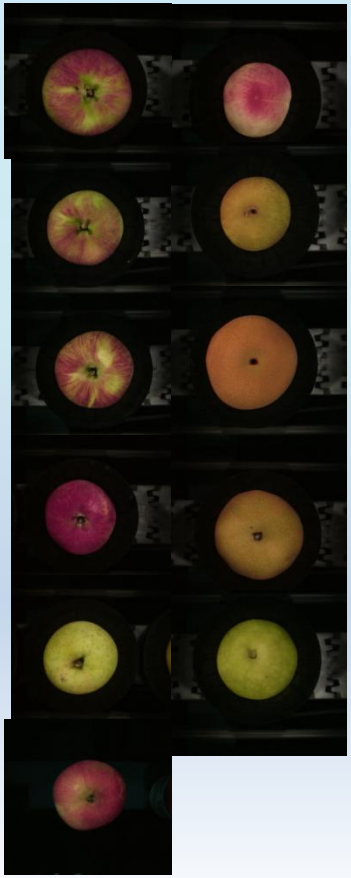
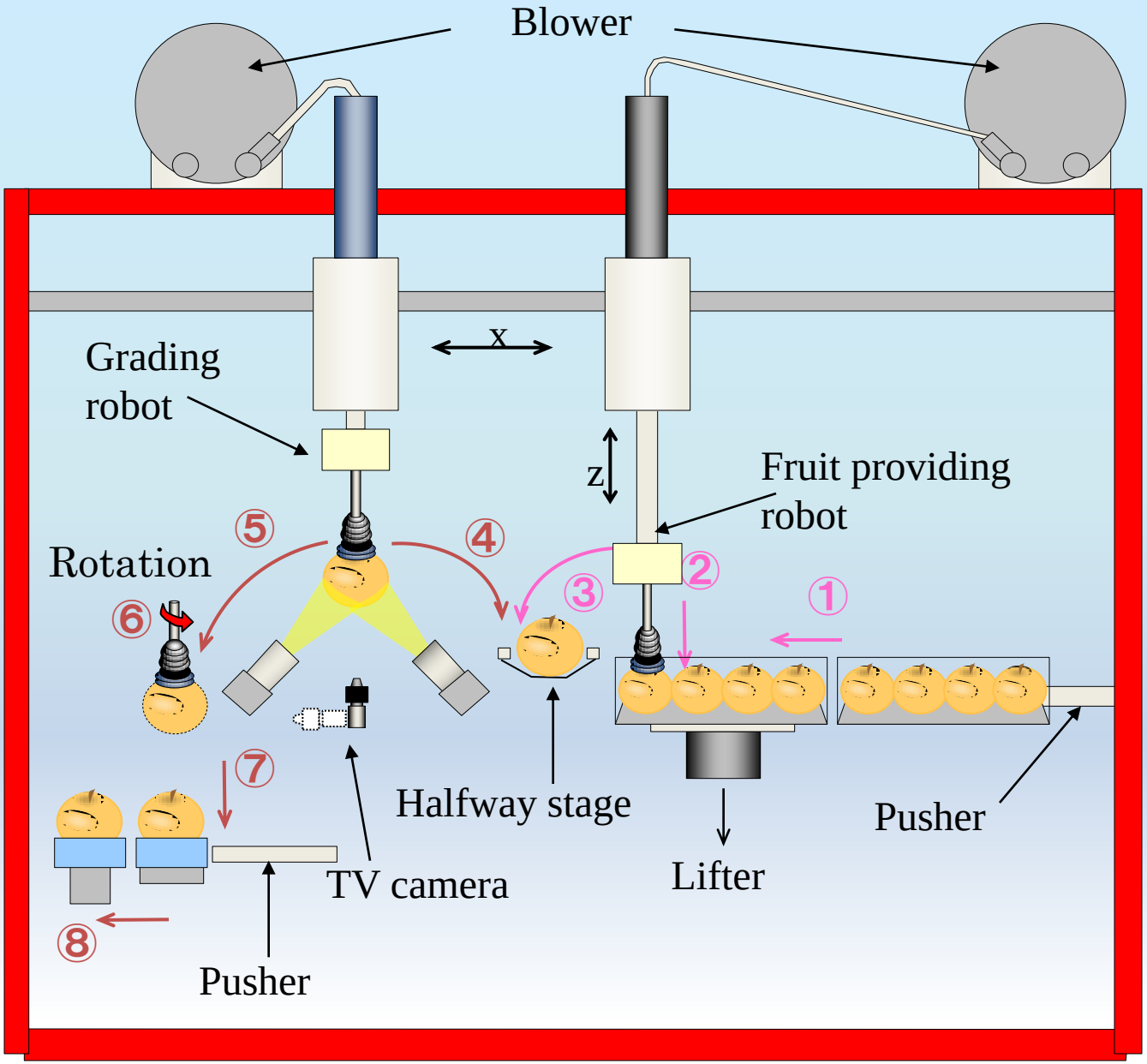
# Constitution of robotic grading system





# History of Agri-robot Researches

**Agri-robot I (Since 1982, for ten years)**

- Adoption of industrial robots
- Investigation of robot mechanisms h… plant properties

**Agri-robot II (Since 1992, for ten years)**

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

**Agri-robot III (Since 2002)**

- Precision Agriculture oriented rob…
- Product information addition, accumulation, an…

**Agri-robot IV (Since 2012)???**

- Human health oriented ro…
- Aged producer supp… robot
- Support of environmental conservation

Seedling production robot

Fruit Harvesting robot

Fruit grading robot

Agricultural robots with diversifying roles

By Kondo

# History of Agri-robot Research

## Agri-robot I (Since 1982, for ten years)

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- Investigation of robot mechanisms based on plant properties

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- Construction of fundamentals of relation “Human-Plant-Robot”

## Agri-robot III (Since 2002)

- Precision Agriculture oriented robot
- Product information addition, accumulation, and utilization

## Agri-robot IV (Since 2012)???

- Human health oriented robot
- Aged producer supporting robot
- Support of environmental conservation

By Kondo

# Desirable Horticultural Approaches from Engineers' View Points for Automation of Harvesting Operation

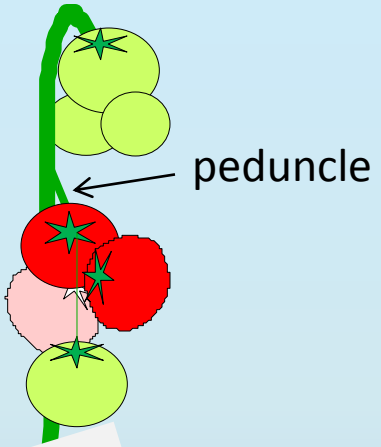
## 1. Variety selection & breeding

1) simultaneous maturing

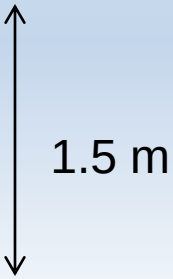
2) longer peduncle

3) appropriate fruit size and number

4) dwarf variety




Biological potential




# Desirable Horticultural Approaches from Engineers' View Points for Automation of Harvesting Operation

## 2. Plant training system and cultivation method

1) separate fruits from leaves and stems

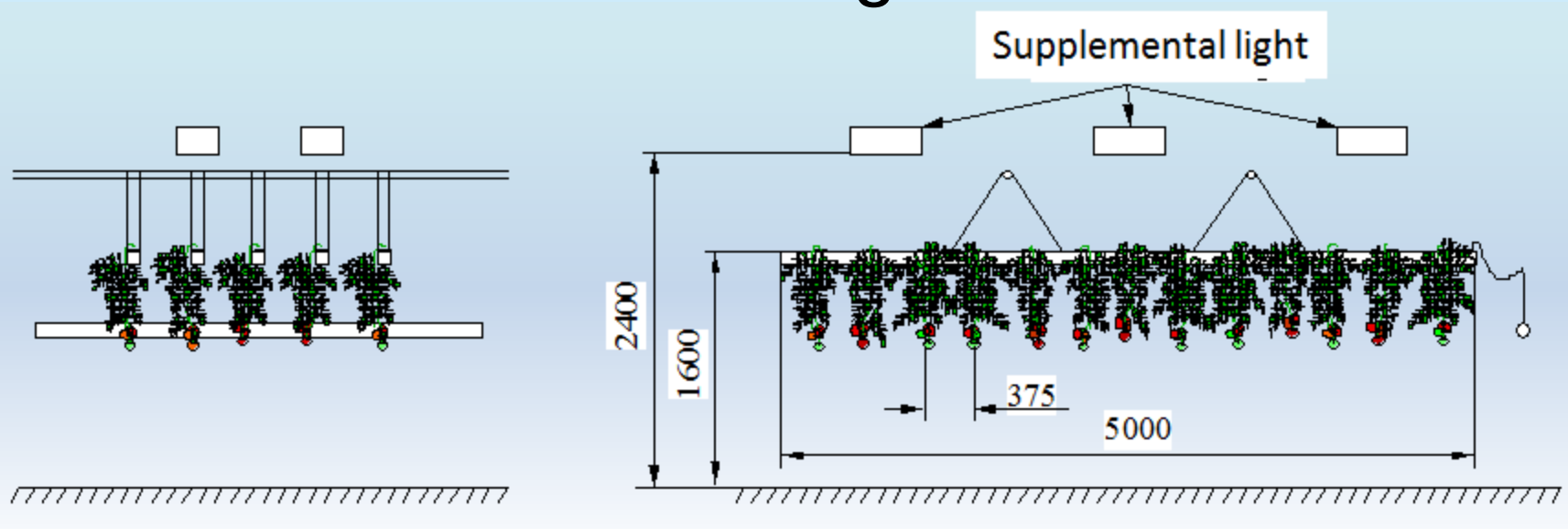
2) similar height (position) of fruits

3) operation addition for helping robot

(e.g. fruit thinning, leaf removing operations)

Physical potential

# STTPS at Rutgers Univ.

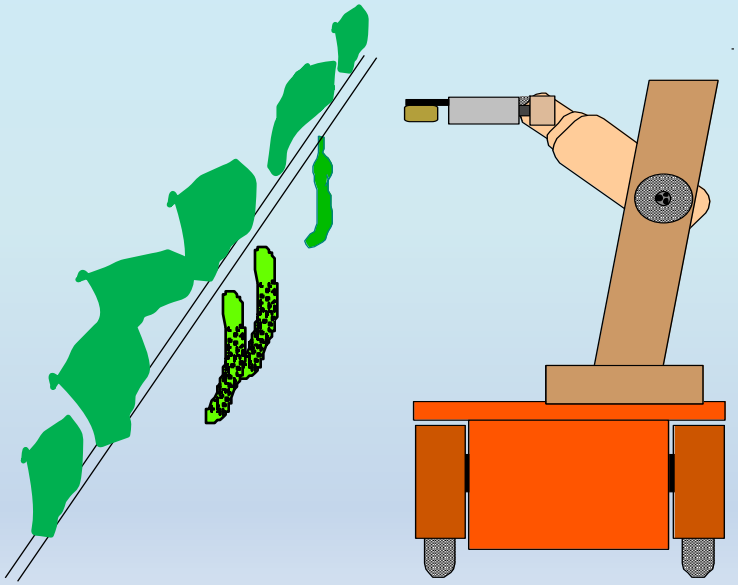



# Tomato Cluster Harvesting Robot

Kyoto U

MAFF

# Inclined Trellis Training



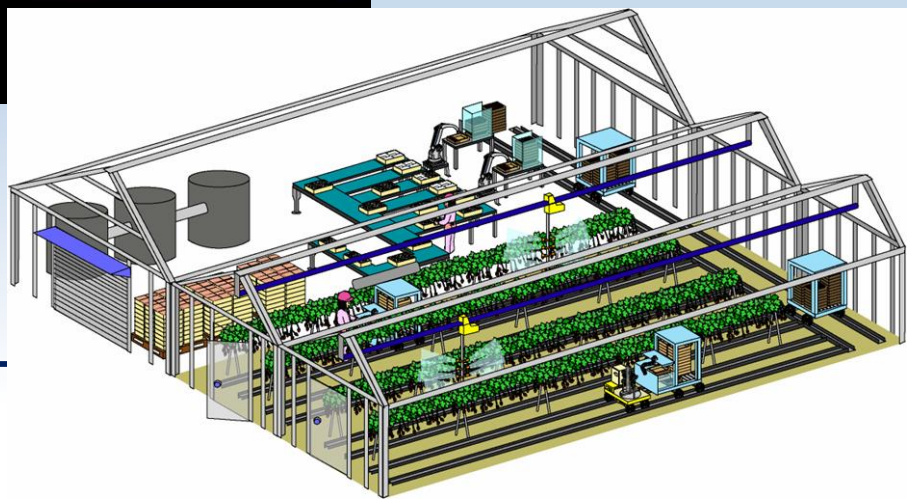
Okayama U

# Trellis Training System for Grapevine

Okayama U

BRAIN and Shibuya

# A new model of strawberry harvesting robot on table top culture



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# Desirable Horticultural Approaches from Engineers' View Points for Automation of Harvesting Operation

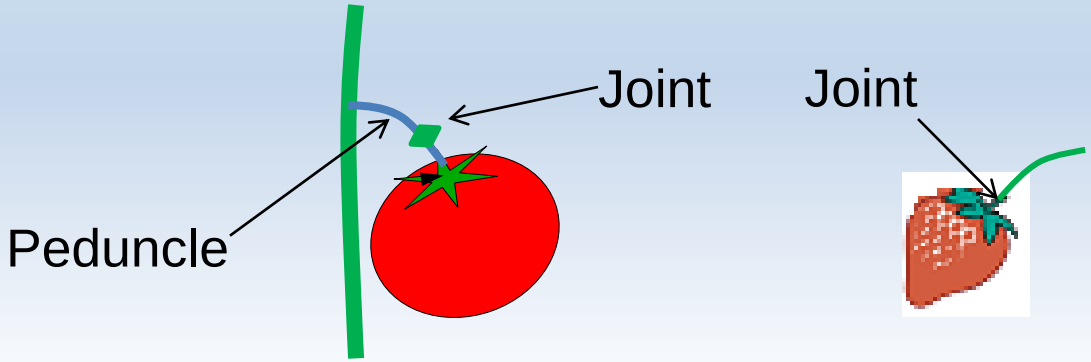
## 3. Chemical control

(Gibberellin, growth retardant)

1) make peduncle longer

2) dwarfing

3) make easy-detach joint in peduncle



# Conclusion

to develop harvesting robots for practical use

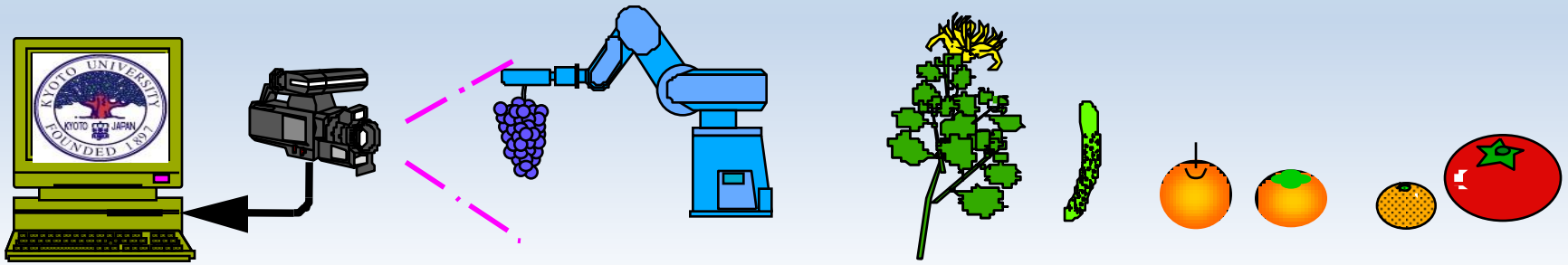
Challenging development of

1) cheaper and higher efficient robot (Engineering approaches)
2) adapting diverse plants' properties (Engineering approaches)
3) in standardized plant conditions with variety selection, training systems, and chemical controls (Horticultural approaches)

Especially, morphological plant feature change such as separation of fruits from others, uniform shape, and easy handling size plants by Biological, Physical, and Chemical methods would be more discussed between horticulturists and engineers for automation in plant production.

# Thank you

Discussions



Coffee Break

English

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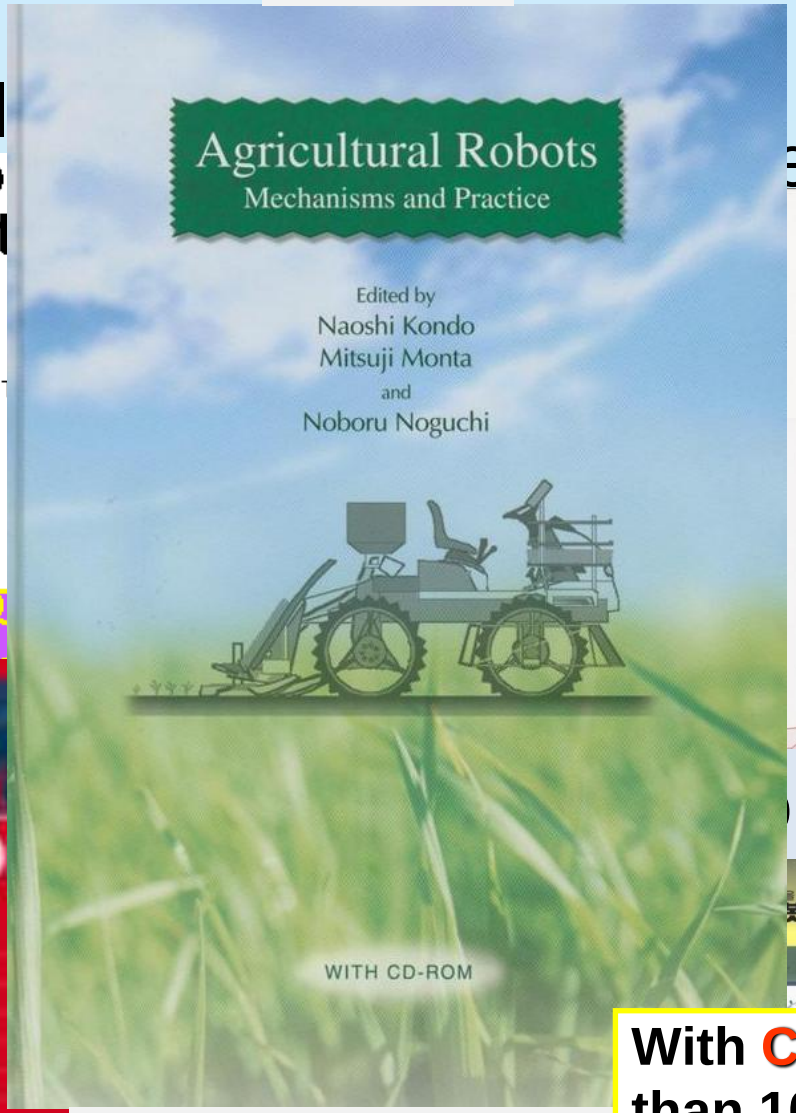
Robotics fo
Bio-product
Systems

Edited by N. Kondo and K.C.




Kyoto Univ. Press, 2011

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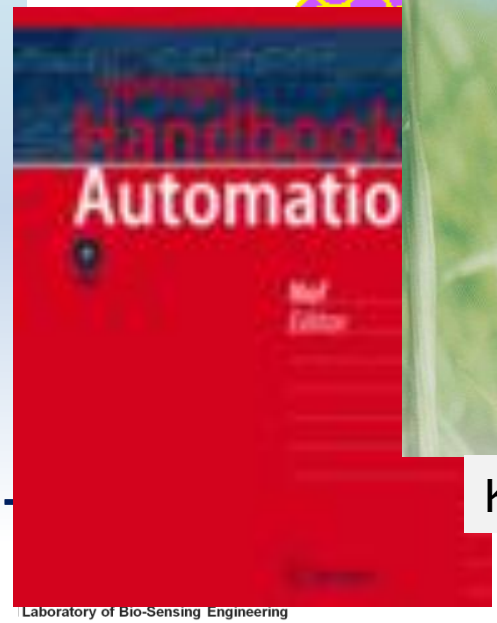


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# Roles of Agricultural robots

To Substitute labor and workers
To Release from heavy, dangerous, or monotonous operations
To increase market value of product,
To produce uniform products
To make hygienic / aseptic production conditions
To give successors a hope for economic sustainability of small high value farm operations

+

**Record of agricultural operations and accumulation of product information as precision agriculture oriented robots**

## An Evolved Grading Robot

Yonjiu, Korea