Present situation and future prospects on fruit harvesting and grading robots

Naoshi Kondo
Graduate School of Agriculture
Kyoto University, Japan
Beautiful Kyoto: Capital City for 1000 years (794-1868)

Population: 1,470,000

17 World cultural heritages
Our University

1897: Kyoto University was founded as the second imperial university in Japan

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).

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

Cucumber (Okayama U)

Cucumber (IMAG, Wageningen)

Tomato (Okayama U)

Cherry Tomato (Osaka Pref. U)
Tree fruit harvesting robots

Satsuma Mandarin (Kubota)

Orange (CEMAGREF)

Orange (U of Florida)

Grape (Okayama U)

Many robots were developed in 1980–1990s
Tomato Cluster Harvesting Robot

Kyoto U

4/11/2012

MAFF
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
A new strawberry harvesting robot in plant factory

BRAIN and Shibuya
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)
4) Various brightness and color temperature of sunlight
5) Variable and complicated plant properties

+ Information from robot

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

Realization of precise informatization for consumers’ various preference and for food safety and security

Support of environmental conservation and aging society in local region

Support of production of functional agricultural products for healthy life

(Based on monitoring functional substances using various electromagnetic waves: X-ray, UV, Visible, NIR, FIR, and THz waves especially in plant factories or in controlled environment.)

Challenging development of

Cheap and high efficient robot supporting aged producers and adapting diverse plants’ properties in complicated and various natural environmental conditions
Agricultural Robots
Mechanisms and Practice

Edited by Naoshi Kondo,
Mitsuji Monta,
and Noboru Noguchi

Kyoto Univ. Press, 2011

With CD-ROM including more than
100 movie files and over 500 color
pictures with English captions!
Fruit Grading Robot

- Pear
- Apple
- Peach
- Persimmon
- Tomato
Constitution of robotic grading system

- Blower
- Fruit providing robot
- Grading robot
- Rotation
- Halfway stage
- TV camera
- Lifter
- Pusher
Information of fruit appearance

Original images

Color conversion images

Processed images

+ Internal quality information
(Sugar & acid contents, rot, ….etc.)
Action and performance of fruit grading robot

Stroke: 1165 mm
Cycle time of the stroke: 4.25 s

Performance of grading robot on a condition of 10,000 fruits/hour
Shipping quantity of fruits
An Evolved Grading Robot

Top cameras

Bottom camera

Side camera

Yonjiu, Korea
Appearance (size, color, shape, defect)
Internal qualities (sugar and acid contents)
Farming support system based on GIS

Management information  Harvesting information

Harvesting robot  Management robot

Fertilizing  Chemical spraying  Irrigation......

Grading robot

Data from grading system can be used for precision farming

On Geographical data

Precise information accumulated by robots

Soil sensor

Field information

Accumulation to DB

• Appearance  
• Internal quality
Roles of Fruit Grading Facility

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 and GIS
6. Contribution to the Traceability system for food safety and security
Price Difference between US & Japan

At Meijier, Columbus OH, and Fuji supermarket, Matsuyama, Ehime, June and July, 2005
Difference between American & Japanese Melons

2 dollar melon (Cantaloupe)
USA

5 dollar (¥500) melon
Japan
Traceability System with a fruit grading robot
Main flow on traceability data

**Grading robot**
- Received date
- Variety
- Container number
- Fruit number

**Barcode reader**
- Reception ID

**Farming operation records**
- Chemicals
- Fertilizers

**PC**
- Producer ID
- Field ID
- Variety
- Container number
- Fruit number

**ROM-Writer**
- Size
- Color
- Shape
- Defect

**Sorting**
- Grade
- ID

**Packing robot**
- Product ID

**Precise information accumulated by robots**
- Farming operation records
- Chemicals
- Fertilizers
- Transportation data
- Environmental condition
- Sales data
- Price, quantity

**Traceability Database**
- Reception ID
- Grading ID
- Product ID issued date and time
- Packing robot No.
- Grading and reception information

**http://www.jau-brand.jp**
Mobile grading machine to manage each tree for more preciseness

(Information from harvesting robot)
Harvesting date and time, location of product

(Information from grading robot) +
Appearance information, Internal quality information

Yield map
Quality map
Tree management
Mobile grading machine in field

- Handle
- NIR sensor
- TV camera
- Roller conveyor
- Turning-over mechanism
- Photo sensor
- Ultrasonic sensor
- Fruit entrance
- Mobile grading machine in field

Kyoto U
Handheld type sugar content sensor
FANTEC
Information to express on above maps:
Sugar content, acidity, fruit color, size, shape, defect, tree height, canopy size
All robots are operated by human.

To keep the traceability (information system) working well, human operators should be faithful, sincere and honest.
History of Agri-robot Research (Summary)

Agri-robot I (Since 1982, for ten years)
- Adoption of industrial robots
- Investigation of robot mechanisms based on plant properties

Agri-robot II (Since 1992, for ten years)
- Fusion between horticultural and engineering approaches
- 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)
- Aged producer supporting robot
- Human health oriented robot
- Support of environmental conservation

By Kondo
Thank you

Any Questions?
Flow of information from field and product

Production information

Field management
- N, P, K, pH, EC
- SOM, MC, Temp., Compactness,

Seedling production
- Crop management
  - Operation record: Irrigation, fertilization, chemical spray, transplanting, pruning

Harvesting
- 3D location of product
- Harvesting time & date
- Crop ID, Size, Color, Disease

Grading
- Appearance (color, size, shape, bruise, disease)
- Internal quality (Sugar & acid contents, rotten core, inside defect)
- Graded rank, Chemical residue, Ingredients
- District name

Field ID (address, height above sea level), Producer ID
Climate, weather information (Temp, humidity, irradiation, precipitation)

Distribution information
- Transportation Environmental condition (Temp., humidity)
- Package type and method, transporting method, time, and distance

Consumption information
- Selling price, selling time, information of arrival of goods, quantity to sell,
- Opinions of costumers (on taste, freshness….)

Selling price, selling time, information of arrival of goods, quantity to sell,
Opinions of costumers (on taste, freshness….)

Field ID (address, height above sea level), Producer ID
Climate, weather information (Temp, humidity, irradiation, precipitation)