Force Control in Fruit Picking Applications

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DER FORSCHUNG | DER LEHRE | DER BILDUNG

What is Force Control

- Motion Control has limitations

Application:

- Safety when working with humans
- Safety when interacting with objects
- Giving Force feedback

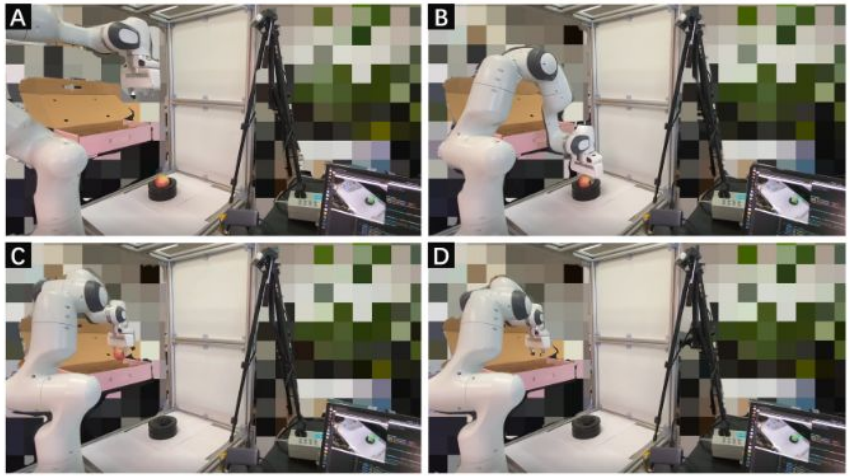

Figure in [12]

Bruno Siciliano and Luigi Villani. Robot force control. Springer Science & Business Media, 1999 [11]
Wang, Qingyu, et al. "Design, integration, and evaluation of a robotic peach packaging system based on deep learning." *Computers and Electronics in Agriculture* 211 (2023): 108013.[12]

Fruit Picking Applications

- Picking up of Fruits

Applications

- Fruit Packaging
- Fruit Sorting
- Fruit Harvesting

Motivation

- Labor Shortage In Fruit Processing Industry

Figure in [2]

Zhongkui Wang, Shinichi Hirai, and Sadao Kawamura. “Challenges and opportunities in robotic food handling: A review”. In: Frontiers in Robotics and AI 8 (2022), p. 789107. [1]
https://www.asplinspo.com/growers/dearnsdale-fruit/ [2]

Gripper Design

- Gripper Design Important for damage prevention
- Consideration Form, Angle of effect and Materials

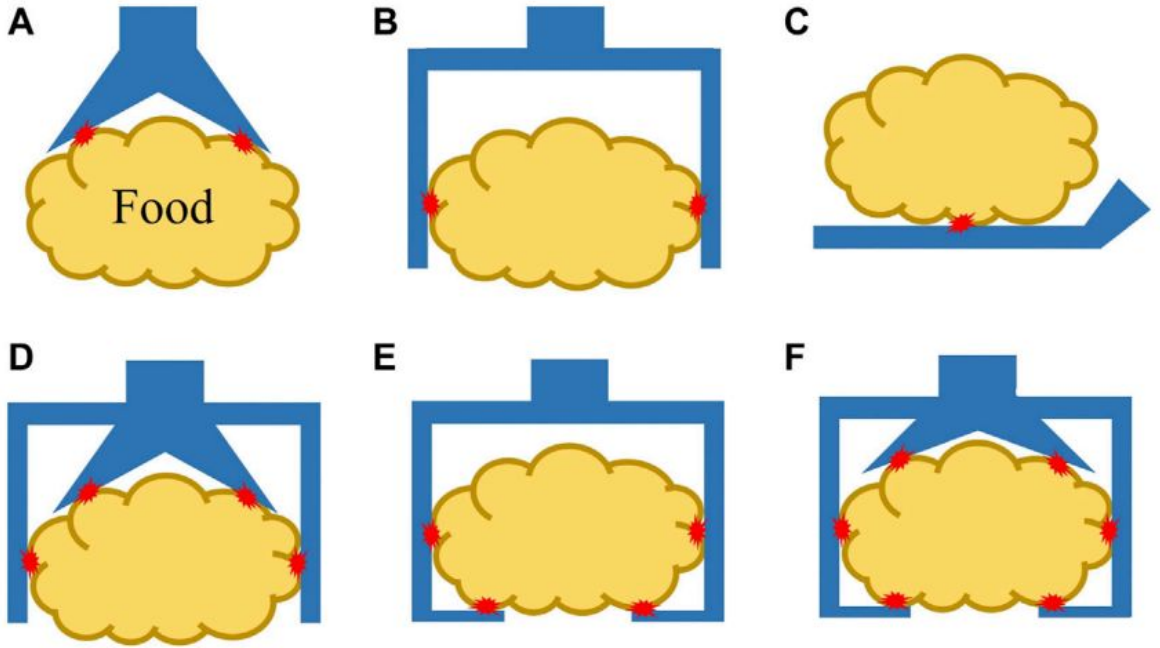

Figure in [1]

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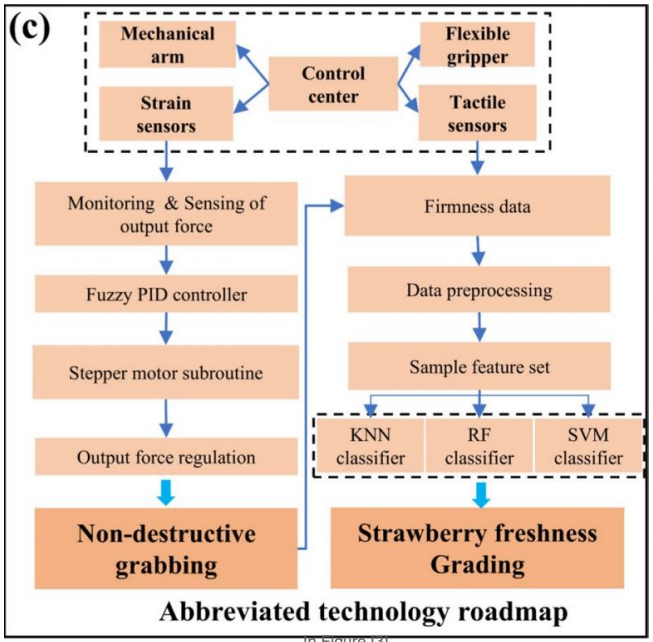
Strawberry Grasping (1/3)

Goal: Pick up Strawberries with 6-DoF Robot arm

- Prevent damage of Fruit
- Detect freshness

Requires

- Force Control System
- Gripper Design

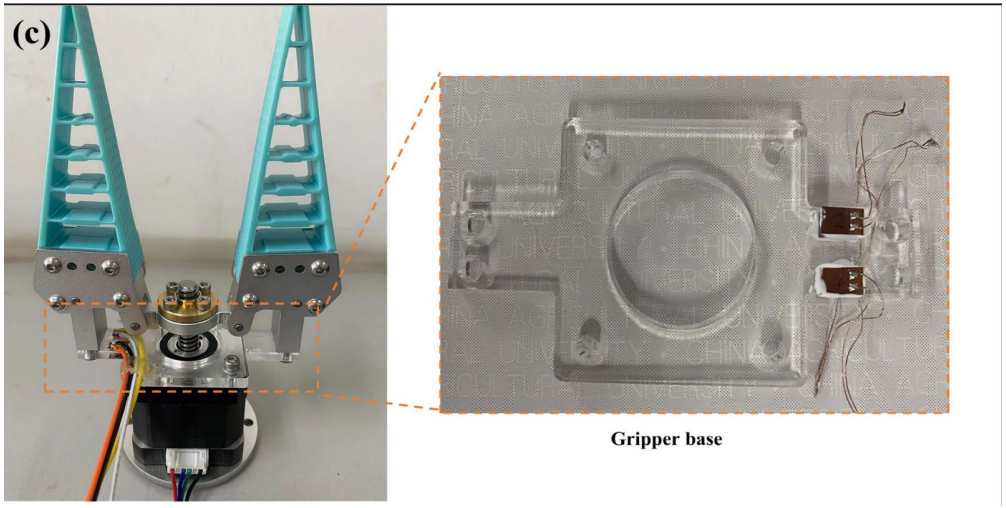


In Figure [3]

Junchang Zhang et al. “Force Sensing and Force Control of Flexible Gripper with Integrated Flexible Strain and Tactile Sensors for Strawberry Non-Destructive Gripping and Freshness Grading”. In: Food and Bioprocess Technology (2025), pp. 1–22 [3]

Strawberry Picking (2/3) - Strain Sensors

- Measuring Forces



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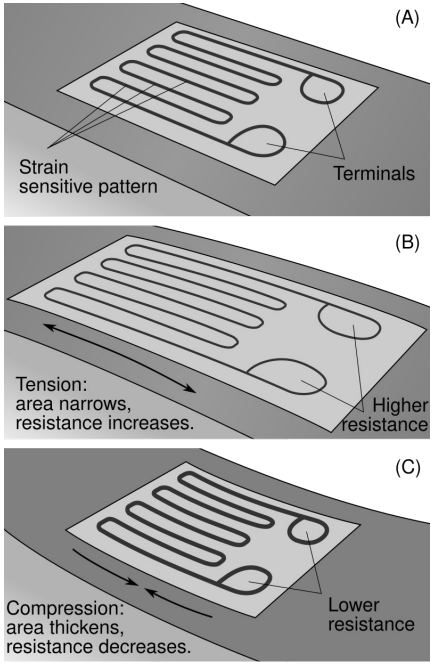


In Figure [4]

Junchang Zhang et al. “Force Sensing and Force Control of Flexible Gripper with Integrated Flexible Strain and Tactile Sensors for Strawberry Non-Destructive Gripping and Freshness Grading”. In: Food and Bioprocess Technology (2025), pp. 1–22 [3]
By Izantux - WikiCommons, CC0, https://commons.wikimedia.org/w/index.php?curid=14933147[4]

Control System Engineering - Regulator

- Systems are Modeled Mathematically
- Differential equations are then transformed via Laplace Transform
- Yields transfer function

$$a_n \gamma^{(n)}(t) + a_{(n-1)} \gamma^{(n-1)}(t) + \cdots + a_0 \gamma(t) = b_m u^{(m)}(t) + b_{m-1} u^{(m-1)}(t) + \cdots + b_0 u(t)$$

$$L[f(t)] = F(s) = \int_0^\infty f(t) \cdot e^{-st} dt \qquad s = \sigma + i\omega$$

$$F(s) = \frac{Y(s)}{U(s)} = \frac{b_0 + b_1 s + \cdots + b_m s^m}{a_0 + a_1 s + \cdots + a_n s^n}$$

Frank Dörrscheidt and Wolfgang Latzel. Grundlagen der Regelungstechnik. Springer-Verlag, 2013. [5]

Different Controllers

Proportional-Integral-Derivative (PID) controller

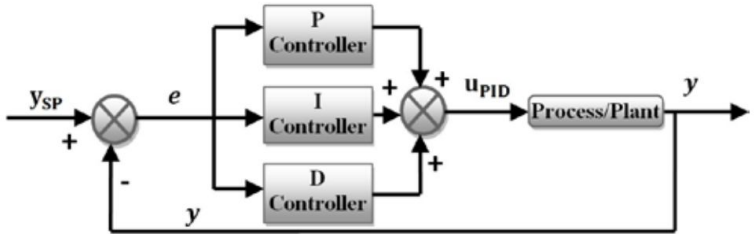


Figure in [7]

$$u_{PID}(t) = K_C e(t) + \frac{K_C}{\tau_I}\int e(t)dt + K_C \tau_D \frac{de}{dt}$$

Equation in [7]

Fuzzy Controllers

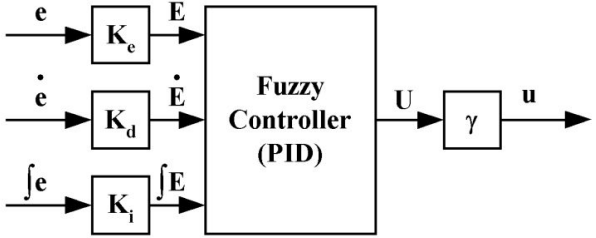


Figure in [6]

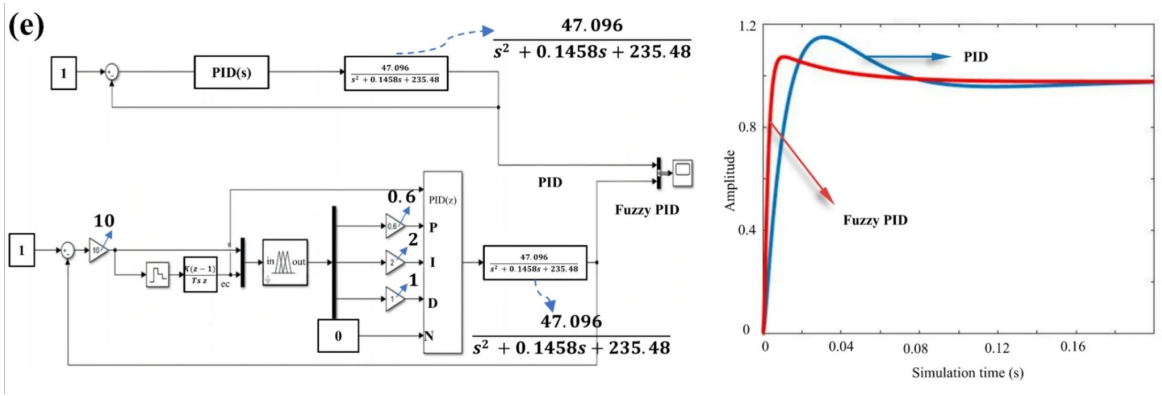
- Add nonlinearities to controller
- Example: Rule based fuzzy Controllers

Engin Yesil, M Guzelkaya, and Ibrahim Eksin. “Fuzzy PID controllers: An overview”. In: The Third Triennial ETAI International Conference on Applied Automatic Systems, Skopje, Macedonia. ETAI Society of Macedonia. 2003, pp. 105–112 [6]

Vineet Kumar, BC Nakra, and AP Mittal. “A review on classical and fuzzy PID controllers”. In: International Journal of Intelligent Control and Systems 16.3 (2011), pp. 170–181. [7]

Strawberry Picking (3/3) - Fuzzy PID Controller

- PID Controller
- Fuzzy Controller



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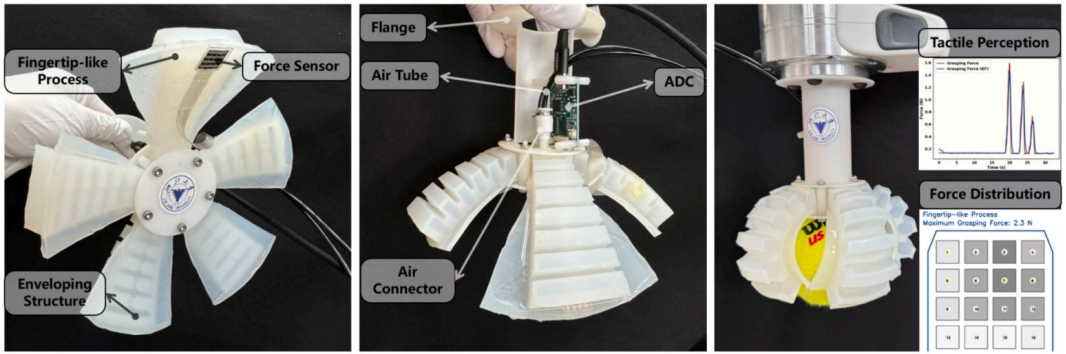
Enveloping Gripper Design

- Pneumatic Gripper
- Bioinspired by food grasping of elephants
- Force Control module



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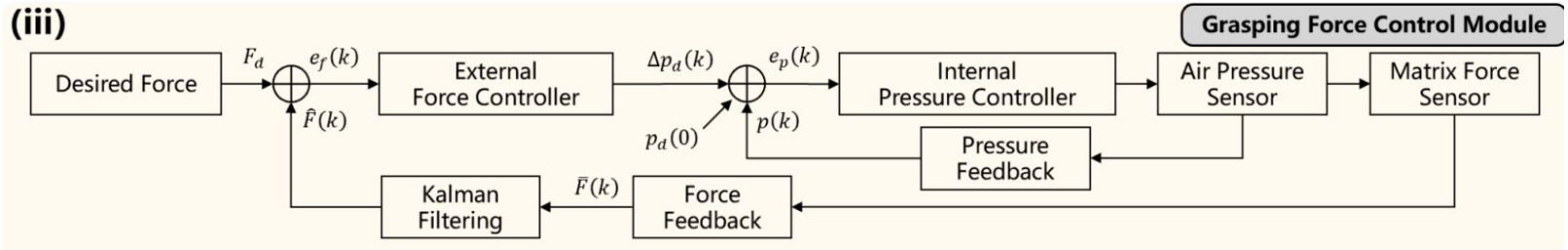

Figure in [8]

Qingyu Wang et al. “Towards reliable and damage-less robotic fragile fruit grasping: An enveloping gripper with multimodal strategy inspired by Asian elephant trunk”. In: Computers and Electronics in Agriculture 234 (2025), p. 110198. [8]

Soft Gripper for Apple Harvesting

- Forces must be low to ensure no damage
- Forces must be high to harvest apple and avoid slipping

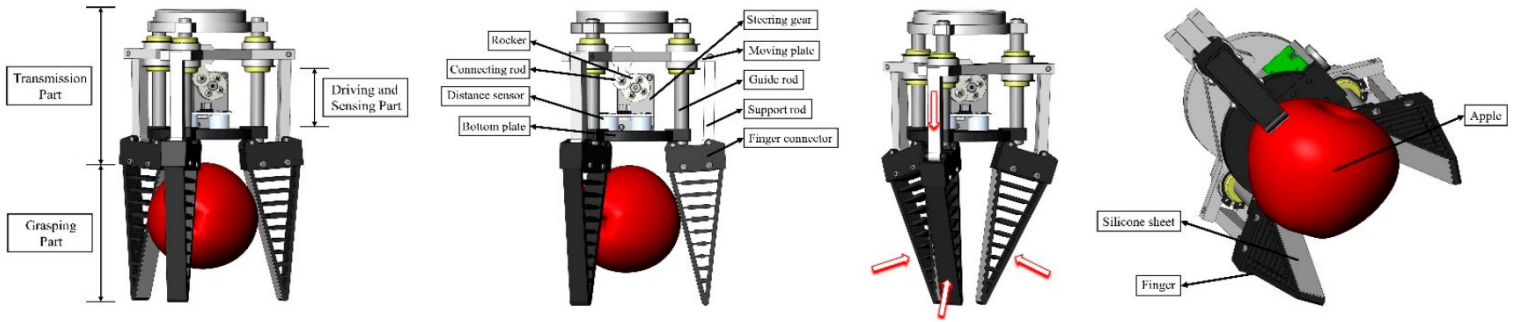

Figure in [9]

Kaiwen Chen et al. “A soft gripper design for apple harvesting with force feedback and fruit slip detection”. In: Agriculture 12.11 (2022), p. 1802. [9]

Further Challenges - Selective Grasping

- Force Control very established
- Grasp pose relevant for required forces
- Apply Visual Based Deep Learning

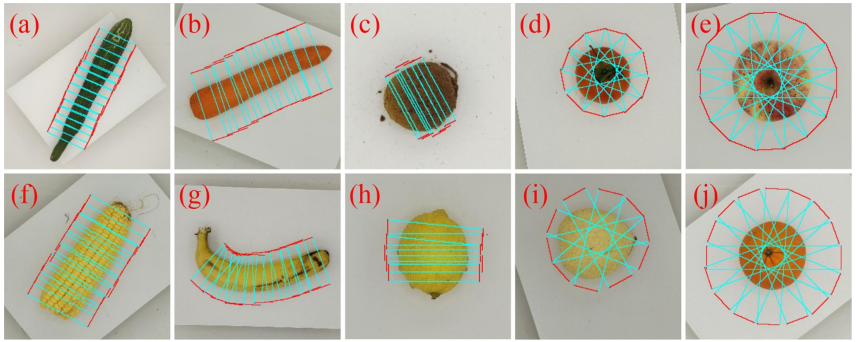

Figure in [10]

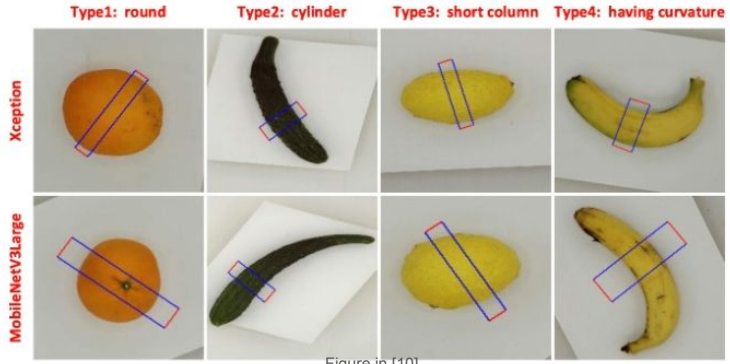

Figure in [10]

Boyuan Cao et al. “Real-time, highly accurate robotic grasp detection utilizing transfer learning for robots manipulating fragile fruits with widely variable sizes and shapes”. In: Computers and Electronics in Agriculture 200 (2022), p. 107254. [10]

Questions?