Soft robotics and handling delicate crops

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Agri-robots
Robotic agriculture: the battle between the big and the small

Agricultural robotics can upend several commonly-held notions, amongst them is the idea that big is better.

In practise this has translated into ever larger and more powerful agricultural machinery.
Agri-robots

If EU workers go, will robots step in to pick and pack Britain’s dinners?

Automation is on the march on farms across the world, but it is costly, and may not come soon enough to fill the gap.

Strawberry pickers, mostly from Poland, in poly tunnels on a farm in Kent. Photograph: Graeme Robertson for the Guardian.

Octopus-like robots are plucking strawberries in Spain, in the US machines are vacuuming apples off the trees, and in the UK they are feeding and milking cows. Robots are taking over fields around the world, and last week food and rural affairs secretary Andrea Leadsom suggested they could help replace the thousands of EU workers who currently help put food on British tables.

And it is not just Brexit that is forcing the agricultural industry to embrace the...
Agri-robots

Tractica

Agricultural Robot Revenue and Shipments, World Markets: 2015-2024

<table>
<thead>
<tr>
<th>Year</th>
<th>Revenue ($ Millions)</th>
<th>Shipments (Units)</th>
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<tbody>
<tr>
<td>2015</td>
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<td>100</td>
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<tr>
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</table>

Source: Tractica

Workers go, will robots step in to feed pack Britain’s dinners?

Robots on the march on farms across the world, but it is costly, and may not be enough to fill the gap.

Farmers, mostly from Poland, in poly tunnels on a farm in Kent. Photograph: Graeme Robertson for The Guardian

Several commonly-held notions, for example, that small-scale, organic, lettuces are always better. In fact, they are often larger and more powerful.

As the number of EU workers who currently help put food on British tables.

Brexit that is forcing the agricultural industry to embrace the technology.
Soft and Adaptive Robotics (SAR) lab
• Soft and Adaptive Robotics (SAR) lab
  • Soft/variable-stiffness robots for real-world applications
    • Picking soft fruits and vegetables
    • Research and education
  • Substantial Research/Innovation funding (>£1.2M)

• Fieldwork Robotics Ltd
  • Plymouth University spin-out company
  • Drive SAR research to commercialization
  • Multi-crop robotic harvesting technology as a service

• Winter 2019: 10+ staff and funded students across groups
- Innovate UK (Fieldwork Robotics Ltd)  
  - Project: “Soft and Selective Raspberry Harvester (SoSeRaH)”  
  - 2018-2020, Principal Investigator (PI). £507,000.

- Agri-Tech in China: Newton Network+ (ATCNN), UK  
  - Newton Fund, UK, 2018-2019. £72,000.

- Agri-Tech in China: Newton Network+ (ATCNN), UK  

- European Regional Development Fund (ERDF), Agritech, Cornwall, UK  

- UoP Proof of Concept funding, “Compliant Autonomous Systems for Agriculture (CASA)”  
  - University of Plymouth, 2016-2019. £79,000.

- Marie Curie Intra-European Fellowship (IEF)  
  - Project: “Developmental Context-Driven Robot Learning (DeCoRo)”  
  - PI: Angelo Cangelosi, Researcher: Martin F. Stoelen.  

- NILS Science and Sustainability Mobility Grant  
  - Project: “Robotics for Sustainable Farming of High-Value Crops in Norway: A Case Study on Sugar Pea Harvesting”  
  - Researcher: Martin F. Stoelen.  
  - European Economic Area (EEA), 2014. €12,000.
Fast manipulation in close proximity to people/obstacles, with noisy sensory data

* Zinn et al., The international journal of robotics research, 2004
Fast manipulation in close proximity to people/obstacles, with noisy sensory data

Collisions with obstacles
• Hard to prevent 100%
• E.g. wooden poles, infrastructure, ground

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Injury to human co-workers
- Dynamic environment
- Head Injury Criterion*
- Cutting mechanisms

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Entanglement
- Cords, wires
- Branches, stems, leaves

* Zinn et al., The international journal of robotics research, 2004
The human muscle-tendon system
The human muscle-tendon system

© Pearson Education Inc., 2011

Vanderborght et al., Robotics and Autonomous Systems, 2013
The human muscle-tendon system

Variable Stiffness Actuator (VSA)

Triceps relaxes

Flexion

© Pearson Education Inc., 2011

Vanderborght et al., Robotics and Autonomous Systems, 2013
Family of VSA robot arms

- Dexterous 7 DOF VSA robot arms
  - All ROS and MoveIt! integrated
  - 5-7 variable-stiffness joints
  - Uni- or bi-directional antagonist setup
  - High degree of modularity

- Started life as a research platform
  - Open source and DIY 3D printable
  - Rapid co-development of hardware and software
  - Now being applied in our agricultural projects

- Range of capabilities to fit different crops:
  - GummiArm: 1 kg payload
  - GummiHeavy: 2 kg payload
  - GH2: 4+ kg payload
China Robot Harvest ++
Selective harvesting of tomatoes in Shanghai

- Government goal to reduce labour requirements in intensive crop production
  - Shanghai is a fast growing, affluent region
  - Hard to attract workers, age is increasing

- Cross-disciplinary consortium

- 4-month Proof-Of-Concept (POC)
  - 2 trips to China, early July and August 2017
  - 2 part-time Engineers hired for 4 months
  - Robotics equipment and prototyping
China Robot Harvest project

Agri-Tech in China Newton Network+ (ATCNN), UK

With thanks:

Rothamsted Research
Newton Fund
DE TAO GROUP
Fieldwork Robotics Ltd
China Robot Harvest ++

• Build on successful POC demonstration of robot arm for selective tomato harvesting

• Quantify and improve performance in longer-duration field testing
  • UK testing summer/autumn 2018
  • Shanghai, China testing January 2019
  • Robustness to variability from lighting conditions, crop variability and in-field conditions

• Draft commercialization plan for full mobile robot platform (image right) with partners
Autonomous and selective raspberry harvesting

• Raspberries - A market ripe for picking robots
  • Manual labour often > 50% of cost
  • No current automated solutions for fresh cons.
• Complex foliage, sunlight, poles, soft fruit ++
  • Local farmers in Plymouth used as testbeds
  • Experimental raspberries grown at UoP
• Recent collaboration agreement with Hall Hunter Partnership
Successful Innovate UK proposal

- 24 month project (> £600k in total)
- Led by Fieldwork Robotics Ltd
- Start: December 1\textsuperscript{st} 2019
- End: November 30\textsuperscript{th} 2020

Inter-disciplinary team

- Fieldwork Robotics Ltd (Dr Stoelen)
- National Physical Laboratory (Dr Dudley)
- University of Plymouth (Dr Howard)
- Hall Hunter Partnership for field-testing
- Field-test complete raspberry picking platform
• Explore selective harvesting for Brassica production in Cornwall
• PI: M. Stoelen, co-I: M. Fuller (Plymouth)
• Part of EU ERDF agri-tech bid
• Use extensive local knowledge in farming, manufacturing, and robotics
• £216k funding, 2017-2019
Collaborators

• **Riviera Produce** (Hayle)
  • End-user input and field-testing sites

• **CNC Design Ltd** (St Columb Major)
  • Motor control and Cartesian robot mechanisms

• **University of Plymouth**
  • Sensors, software and robot manipulators for agriculture
  • Ongoing projects on raspberry and tomato harvesting

• **Robotriks Ltd** (Par)
  • Industrial-grade servo actuators

• **Teagle Machinery Ltd** (Truro)
  • Strategic partner, consult on agricultural machinery
3D vision and modelling

First experimental in-field deployment

Cutting and grasping approaches and mechanisms

Real-time centroid localization

Growing experimental crop on UoP campus

Maturity check (summer varieties)
Thank you