Farming with robots

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Harper Adams University

- Founded 1901 by Thomas Harper Adams
- Crops, Animals, Food, Land and Engineering
- Circa 2500 students
- Engineering department
  - Circa 300 students, 20 academics, 10 technical staff
  - Agricultural Engineering
  - Automotive Engineering (off highway)
  - Mechanical Engineering
  - Applied Mechatronic Engineering MSc
- Research into robotic agriculture
National Center for Precision Farming

- Agricultural drone training, development & testing
- Autonomous tractor
- Laser weeding and micro droplet application
- Robotic seeding and spraying
- Robotic phenotyping and crop scouting
  - Sub canopy sensing robot
- Autonomous mower
- Robotic strawberry harvesting
- Phenotyping robot for grass
- Hands-free-hectare
Agricultural Engineering Precision Innovation Centre (Agri-EPI)

- Private company based at Harper Adams University
- £18 million government investment in new company hubs to develop Precision Agriculture
- Help the UK’s agri-food sector develop with advanced technologies that increase productivity and sustainability.
- Company to company and company to university R&D
- The Centre has hubs in Edinburgh, Harper Adams and Cranfield Universities.
- 27 instrumented satellite farms
- 130 commercial collaborating companies
- ERDF project to facilitate innovation (Marches LEP)

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Farming in the future?

- Identify weaknesses in current farming system
  - Modern agriculture uses too much energy
    - Fuel in damaging and repairing the soil each year
    - Expensive chemicals being wasted by going off target and causing pollution
  - Large machines and practices are damaging the soil
    - Compaction and loosening every year
    - Intensive cultivation looses soil organic matter
  - Growth through economies of scale coming to an end
    - Machines have getting bigger due to driver costs but are now at their maximum size
    - Large machines are only good for large fields and small fields cannot use them

- Drivers for change
  - More sustainable food in a growing world population
  - Improve on-farm economic viability
  - Desire to have less environmental impact
  - Tighter legislation from EU and UK
  - Energy prices increase
  - More volatile weather due to climate change
  - More competition from world food prices

- Crop production must become more flexible and efficient
  - Intelligently targeted inputs
Future trends

- Agriculture has a 57% potential for automation
The Perfect Storm in UK agriculture after BREXIT

- No production subsidies
  - Farming subsidies cut like NZ
- Vote to restrict EU labour
  - No seasonal harvesters
  - Higher wages to attract British workers
- Devaluation of pound
  - Good for our exports
  - Bad for imported inputs
- Lower sustainability
  - Growers now planting less
  - Growers moving crops to cheap labour

- Technology alleviation
  - Some tasks can be automated
  - Significantly reduce the costs of production
  - Could be made in the UK
  - Move from Precision Farming to Robotic Agriculture
Farming systems

• Currently like an industrial production line
  – Maximising production (yield)
  – Large tractors doing the same work everywhere
  – Based on blanket application of energy (fert, spray,...)

• Need to move to flexible manufacturing
  – React to changes in real-time based on current conditions
    • Weather, growth, prices, legislation, incentives
  – More information intensive
    • Maximise gross margins
    • Manage risk
    • Minimise environmental impact
    • Automation
Economies of scale

- Big tractors and big implements
  - Increasing work rates and economies of scale reduces;
    - Driver costs
    - Cost and time per hectare
  - Large capital investment
  - Reached maximum size due to railway tunnels
    - No more savings through larger economies of scale
  - Good for large fields, cannot be used in smaller fields
    - Small to medium size farms and fields have the greatest potential for increased production with appropriate tech.
Limitations of big machines

– One size fits all
  • Large tractors often doing small work
  • Rarely using full power

– Boys toys
  • Big shiny tractors are always impressive
  • Small smart robots are also fun!

– Need for speed results in a self fulfilling prophecy
  • Small working window needs a bigger machine but the bigger the machine the smaller the working window.
  • Horsepower does not help when weight is the problem

– We cannot change the soil or the weather but we can change the tractor
Compaction

- Up to 90% of the energy going into cultivation is there to repair the damage caused by large machines.
- Repeated damage year after year:
  - Plough/damage, plough/damage, ...
- Economic cost of compaction in England and Wales: c. £0.4 bn/annum (Morris et al. Cranfield University, 2011)
- If we do not damage the soil in the first place, we do not need to repair it.
- Natural soil flora and fauna produce the ideal soil structure (let the worms do the work).
- Move towards Controlled Traffic Farming and ultra light machines.
Four phases of mechanization

Establishment

Scouting

Crop care

Selective harvesting
Robotic seeder

• Ultra light, zero draught force
  – No agronomic compaction
  – Put seed into the ground in any weather
• Micro tillage
  – Cultivate for each individual seed position
• Use vertical or rotary seeding methods
  – Punch planting
• Seeding depth to moisture
  – Improve germination rates
• Permanent planting positions
  – Same place each year
Ultra light seeding robot

- Less than 40kPa (6PSI) under the contact patch
- Does no agronomic damage even at field capacity
- Can seed the ground in any weather conditions
Crop scouting

- Working with agronomists by giving near-real-time data over the whole farm
- UGVs (Unmanned Ground Vehicle)
  - Phenotyping robots
    - Crop trials to evaluate new genotypes
  - Scouting robots
    - Targeted agronomic measurements
- UAVs (Unmanned Aerial Vehicle)
  - Rapid assessment technique
  - High resolution imagery
    - Visible: Crop cover, growth rates, flooding extent, late emergence, weed patches, rabbit damage, nutrient imbalance
    - Non-visible: NDVI, Thermal, multispectral
    - Sensor limited by weight and power
Agricultural Drone Centre

• Part of the NCPF
• Working with
  – Civil Aviation Authority
  – Chemical Regulation Directorate
  – Many drone companies
• Spray testing laboratory to accredit drones to use spray in the UK
Crop scouting; Dionysus robot

- Crop scouting robot for vineyards
- Build by Harper Adams MEng students for the University of Athens
- Software Architecture for Agricultural Robots
- Thermal camera for irrigation status
- Multispectral camera for nutrient status
- LIDAR for canopy extent and density
Sub-canopy scouting robot
Robotic Weeding

- Hand weeding costs £2000 per hectare
- 80% grass weeds in UK herbicide resistant
- Discussions to ban Glyphosate
  - Do not ban Glyphosate, ban the dumb sprayer wastes the chemical
  - Only apply chemical directly on to the target leaf
- 10 years & $250m for new active ingredients (not happening)
- Physical weeding alternatives
  - Mechanical weeding
  - Micro droplet spraying
  - Laser weeding from 3D imaging
Autonomous tractor

Steering from LIDAR

GPS to LIDAR steering test
Selective harvesting

• Between 20-60% of harvested crop is not of saleable quality
• Only harvest that part of the crop which has 100% saleable characteristics
  – Phased harvesting, immediate replacement seeding
• Pre harvest quality and quantity assessment
  – Grading / packing / sorting at the point of harvest
    • Add value to products on-farm
  – Grade for quality
    • Size, sweetness, ripeness, shelf life, protein etc
  – Minimise off farm grading and sorting
  – Add value to on-farm products
Selective harvesting and grading strawberries

- Stereo RGB vision (Colour and size, 3D position of peduncle)
- NIR for sweetness, shelf life, quality
- Packing at the point of harvest
Stereo video identifying strawberries
Picking robot; not touching the fruit
Hands Free Hectare

- Produce the world's first automated crop
- Grow one hectare of spring barley without anyone going into the field
- Crop surveyed and sampled by drone
- Soil sampled by robot
- Drilled and sprayed by robotic tractor
- Harvested by robotic combine
  - 3.5t of barley to be made into robotic beer!
Conclusions

- Mobile robots will be used commercially in the horticultural sector first
- Working with two start-up companies looking for vc
- Robots will be very disruptive but will have significant benefits
- Increased yield will come though improving smaller fields
- We are now designing the new systems and trying to understand the implications
- We are always interested in partnerships
Incorrect assumptions about robotic agriculture

• Robots are only for big fields
  – Big fields have big equipment that is very efficient.
  – Small fields cannot be currently used with the same efficiency
  – Small robots can increase the efficiency in small fields

• Robots will be too expensive
  – Current big tractors need investment of £100k+ which farmers already pay, plus driver costs
  – Cost of a robot will be about £20-50k and will not need a ‘driver’

• Robots will reduce rural workforce
  – Big tractors have already reduced the rural workforce from what they were 70 years ago.
  – We will still need a farm manager to plan the tasks
  – Still need an agronomist but will be supported by better real-time information
  – The tractor driver will need new skills to become a robot operator.
  – Seasonal labour will be significantly reduced

• Robots will do everything
  – Robots will be used in niche areas like weeding and scouting
  – Large manned tractors will still be needed for road work and heavy logistics

• Robots are not safe
  – New system has seven levels of safety
  – Driverless cars on road, why not tractors?
  – A person is always in charge of the robots via a smartphone.

• Robots are too complex and will need an operator with a PhD
  – With good design a robot should be as easy to use as a smartphone
  – Leapfrog technology
  – Embedded smarts

• Robots are for the future, not now
  – Why not now?
Robots as a service not a product

• Traditional business model
  – Build product and sell it
  – e.g. weedkiller
    • Loss of control after sale
    • Open to misuse

• New business model
  – Sell service with embedded product
  – E.g. eradication of weeds
    • Can use any technology (such as laser weeding)
    • Continual feedback on product and its use
    • Easily updated