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
- "University of the year" from student feedback. April 2016

National Center for Precision Farming

- Agri-drone centre
- 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)

- £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 will have hubs in Edinburgh Harper Adams University and Cranfield University.
- 110 companies and institutions in all

www.agri-epicentre.com

Farming in the future?

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- 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

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

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- Up to 90% of the energy going in to cultivation is there to repair the damage caused by large machines
- Repeated damage year after year
  - Plough/damage, plough/damage, …
- 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

Farming with robots

- Agricultural robotics is a new systems concept to help improve;
  - Food sustainability in a growing population
  - Greatest increase in production from the smallest fields
    - Average size of fields in Asia is about 1 acre
  - Lowering the cost of food production
  - Reducing the energy needed in agriculture
  - Protect environmental services
  - Very disruptive
  - Making crop production significantly more efficient

New concepts

- Zero draft force (no tractor)
- Intelligently targeted inputs
  - Micro tillage
  - Microdroplet application

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

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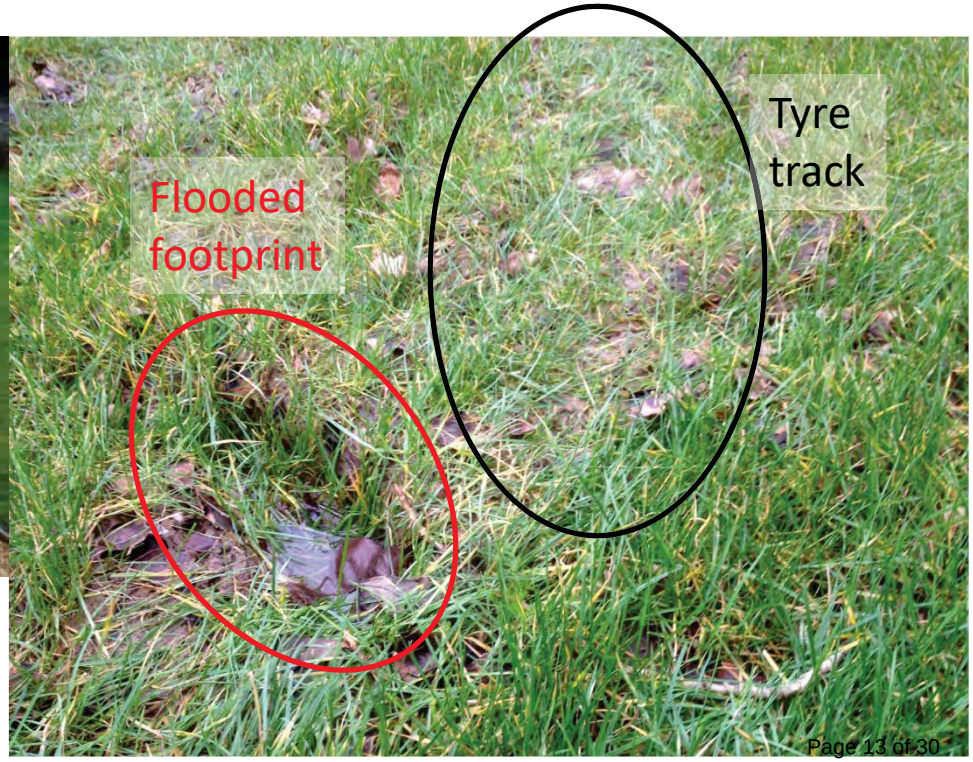
- Less than 40kPa (6PSI) under the contact patch does no agronomic damage even at field capacity
- Can seed the ground in any weather conditions

February 2014



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

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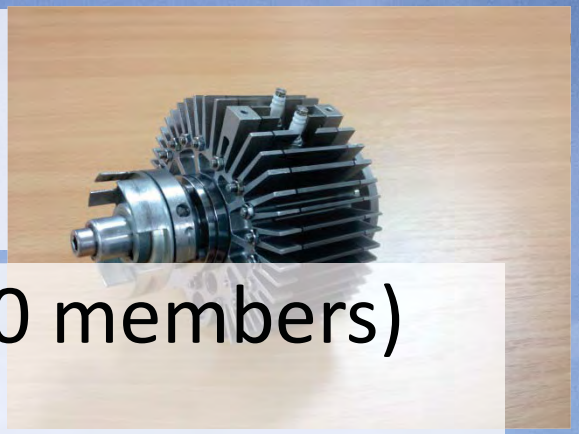
2nd Generation UAS



- Drones for farming NCPF SiG (400 members)
- Ag training for drone pilots
- Picocopters to megacopters
- Tethered UAVs
- Self docking
- Automated logistics
- New engines
- Self guided
- Collaborative M2M

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

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- 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

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Robotic Weeding

- Mechanical weeding
- Micro droplet spraying
- Laser weeding

The Royal Veterinary and Agricultural University

Intra-row Weeding with a Cycloid Hoe

Denmark, May 2006

Robotti

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MicroDot spraying

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- Machine vision recognises the leaves of the plant in real time and records the position and speed
- MicroDot sprayer puts chemical only on the leaf of the plant saving 99.99% by volume

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Laser weeding

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- Machine vision recognises the growing point of the weed
- Laser kills the weed by heating the growing point
- Saving 100% herbicide
- Harper Adams University is now building a real-time robot to laser and microdot weeds
- Funded by a major agrochemical company 2014-2017

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Autonomous tractor

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


MASSEY FERGUSON
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Selective harvesting and grading strawberries

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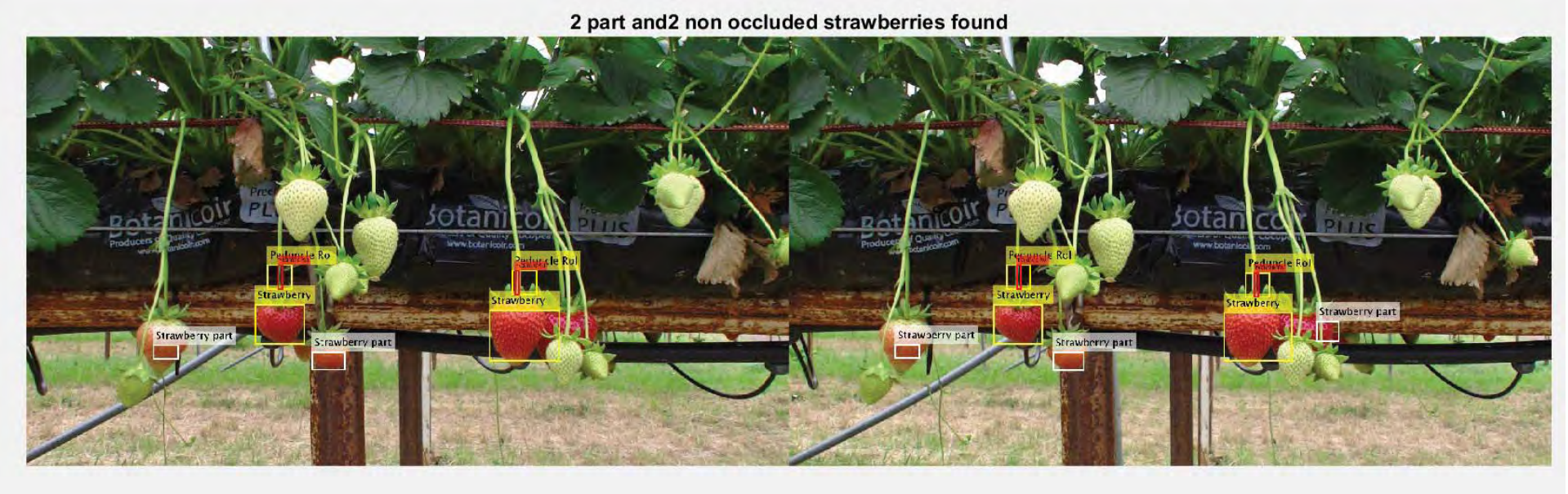
- Stereo vision for size and position
- Picking and grading at the point of harvest



Conclusions

- Mobile robots will be used commercially in the arable and horticultural sectors
- Working with two start-up companies
- 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

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- 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?

Service not product

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- 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