How feasible is Robotic Agriculture?
Designing systems for the farm of tomorrow

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A history of the future: Old concepts of future farming

Snyder 1885
Factory farming
Just remove the driver

Current trend for agricultural equipment to get bigger

- Advantages
  - Current system very effective
  - Reduced labour cost/ha
  - High work rates/hour
  - Economies of scale

- Disadvantages
  - High cost of operator
  - High capital expense
  - Good for large farms & fields
  - Reduced flexibility
  - Reliability?
  - Subsoil compaction?

Management units reaction of scale

- Conventional or Traditional Farming
  - Field
  - One rate

- Precision Farming
  - Sub-Field
  - Variable dose rate
  - Patch application

- Single-Plant-Care or ‘Phytotechnology’
  - Single Plant
  - Individual dose rate

A systems approach

- Develop new generation of machinery based on plant needs
  - Allow us to do operations we cannot do now, or find too expensive or time consuming
  - Low energy, intelligently targeted inputs
  - Small area or plant scale operations
  - Very low compaction
  - Modular and scalable
  - Cost effective
  - Incremental investment
  - Integrated fleet management
System implications

- Environment
  - Minimal energy inputs
  - Allows controlled biodiversity (retain non-competitive weeds)

- Economics
  - Lower labour costs
  - Incremental investment, scalability, redundancy

- Social
  - Public perception of agriculture improved
  - Public acceptance and liability easier with small vehicles

- Opportunities
  - Use existing research sensors
  - Use latest ICT developments in agriculture

Wastes
- Biomass
- Off farm pollution

Light/Air/Rain

Fossil fuels
- Machinery/Fuel

Fertilizer
- Pesticides
- Herbicides

Food
- Biofuels
- Energetic autonomy

System requirements

- Light weight
- Small and autonomous
- Computational (and energetic) autonomy
- Weather independence / dependence
- Redundant system architecture
- Graceful degradation
- Communication
- Identifiable behaviour
- Self awareness
- Working at night
- ...

Robotic agriculture

- Multiple small intelligent machines replace large manned tractors
- Multiple machines to increase work rates
- Longer working hours
- Safe and reliable
- Easy to manage
- Robot shepherd
- Incremental costs
- Re-invent mechanisation to give smarter machines that can care for individual plants

Autonomous behaviour

- Purely deterministic tasks
  - Can be determined beforehand
  - Uses a priori knowledge
  - Can be optimised e.g. a route plan

- Purely reactive tasks
  - Reacts to unknown situations with defined behaviours
  - Does not need to recognise every situation
    - Only needs to recognise class of problem

- Hybrid system
  - Deterministic and reactive

Deterministic route planning

- Plan an optimal route to follow beforehand
  - Manned or unmanned operation
  - Field segmentation
  - Optimise Productive/non-productive distances

- Craft knowledge
Phytotechnology (autonomous plant scale husbandry)

- Establishment
  - Seed mapping
  - Highly accurate positioning
  - ...
- Crop care
  - Mechanical weeding
  - Micro spraying
  - Laser
  - ...
- Selective harvesting
  - ...

Reduction of energy inputs

- Up to 90% of the energy going into cultivation is there to repair the damage caused by the machinery in the first place.

Compaction in field gateways

New terminology

Current seed mapping

Ultra high accuracy seeding

- High accuracy placement of seed
  - In a predefined pattern
  - Synchronised planting
- Equal space per plant
- Grid
Synchronised planting

Orthogonal inter row mechanical weeding (Organic farming)

High accuracy inter-row weeding with side shift toolbar

Autonomous crop scouting

- Low power, non contact assessment of crop
- Nutrient stress (multispectral camera)
- Diseases (visible camera, biosensors)
- Crop height/growth (ultrasonic rangefinder)
- Weeds (visible camera)
- Measurement of field trials
- Up to 250 plots assessed per day!

Broad leafed weed sensing and spraying

- Camera
- Recognize broad leafed weeds
- Light shields
- Spray boom
- Nozzle control
- Intelligence
- Only spray the broad leafed weeds
- Significantly reduce inputs
**Weed recognition: Active shape recognition**

- Seed map gives initial guidance points
- Recognise weeds in close-to-crop area (ASR)
- Microspray only the weeds

**Microspraying**

- Black Nightshade (*Solanum nigrum*)
- 100 plants per m²
- Glyphosate applied at 720gm/ha - 1gm/ha
- 94% efficacy
- Intelligent placement

**Concept Autonomous machine spreading**

- Spray a 10m yard mature
- Route plan - replication map
- Variable rate application

**Mechanical weeding by hand!**

- Very expensive
- Repetitive and boring!
- Should people be asked to do this?
The Royal Veterinary and Agricultural University

Intra-row Weeding with a Cycloid Hoe

Denmark, May 2006
**Denmark: Hortibot**
- 4WD 4WS
- Based on Spider
- Range of tasks
  - Grass cutting
  - Spraying
  - ... Vision and/or GPS guided
  - Unskilled operator
  - Constant reporting of status
  - Internet data logging

http://www.hortibot.dk

**Finland; Remote controlled tractor**
- The 40 hp Modulaire tractor
- Tracks for low ground pressure
- Remote radio control
- Front and rear Linkages

**America; Autonomous tractor**
- Prototypes by John Deere
- Orchard spraying, field scouting, grass cutting

**Japan; Autonomous tractor**

**Greece; Crop care robot**
- Supportive Autonomous Vehicle for Agriculture
  - Designed by student group
  - Made by local blacksmith using standard parts

**Robotic variable rate chemigation**
- Robotic Irrigation
  - Wetted pattern
  - Irrigate into corners
  - Application map
  - Instantaneous correction of:
    - Wind speed
    - Wind direction
    - Chemigation
System Architecture For Agricultural Robots (SAFAR)

- Funded by the Douglas Bomford Trust
- Provides software framework for development
- Microsoft Robotics Development Studio (MDRS)
- Free at www.unibots.com

Conclusions

- Equipment is going to get smarter
- Improved automatic control of well defined tasks
- Automated data gathering
- Better processing into real information
- Possibility of fully autonomous vehicles with sensible behaviour in given contexts
- The chance to design and build a complete new small smart mechanization system.