Precision Autonomous Farming
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What this presentation is about...

- Thoughts on how to leap into modernization and complete automation of broad acre farming?
- What is the current state?
- What are the positives and negatives of it?
- What is the proposed complete approach?
- How can that be achieved?
- What have we achieved at UNSW Sydney towards this goal?
Confusions!

• What is Precision Agriculture?
  • Spatially accurate measurement of the agronomical parameters and the spatially accurate precision application of agronomical substances.

• What is Precision Farming?
  – Spatially accurate operation of farm machinery. This includes their use for Precision Agriculture as well as other more prevalent operations such as seeding, weeding, fertilizer and pesticide application and harvesting.
Jargon

• Broad acre crops
• Seeders/Air seeders
• Ground compaction
• Controlled traffic
• Inter row cropping
• Stubble interference
• Crabbing
Broadacre crops

• Barley, wheat, canola, grass grown in thousands of hectares of land.
• The land is generally flat and unobstructed.
• From one boundary to another, the distance could easily reach a few kilometres.
• Our trial field is approximately half a km by half a km.
• Small undulations and sloping terrain is possible.
Seeders/Air Seeders
Ground Compaction

• Large Machinery operation results in 20% loss of land due to ground compaction
Controlled Traffic

• Ground compaction is limited to 20% through controlled traffic. It fixes the crop layout orientation.
Inter-row Cropping and Stubble Interference
Crabbing

• Undesirable lateral movement of the implements.
Why full automation?

• In Australia, farming hands decreased from 330,000 by 100,000 over a period of 6 years.
• Family farming is no longer manageable.
• This results in corporate takeovers.
• Stakeholder influence
  – OH&S, Share prices and dividends
  – Compliance
• New outlook is to run them like factories where automation is key to profit making.
• **Autonomous farming is a survival need.**
What is the quantum leap?

- Modular systems
- Complete elimination of controlled traffic
- Complete elimination of crop localization.
- Round the clock operations – day and night.
- Completely autonomous operations from seeding to harvesting.
- Extreme precision – 2cm accuracy in seed drop.
- This precision cannot be maintained by human operators – hence need to be autonomous!
Why such a High Accuracy

- To be able to use inter-row spacing for traffic.
- Crop row pitch $\Rightarrow$ 31-32 cm
- Wheel width $\Rightarrow$ 20 cm
- Wheel path width with 2cm accuracy $\Rightarrow$ 24 cm
- Safety margin $\Rightarrow$ 4 cm
- Same autonomous system can repeatedly traverse the cropping land for other operations without crop damage
- Eliminate the need for crop localization
What are the Advantages?

• Low capital outlay. Modular 3m wide machines instead of 8-10 m wide machines. Some extreme machines are 120 feet wide.

• Elimination of controlled traffic means 20% more arable land and arbitrary orientation of crop layout. Crop layout is no longer stuck with controlled traffic directions.

• Precision inter-row cropping is possible. This will make the wheels travel on stubble hence low rolling resistance.
Other Advantages...

• Inherently fully autonomous.
• There will be no persons to sustain injuries.
• No operators to endure extreme heat.
• Elimination of a major cost item – cabin comfort!
• In a multiple modular systems scenario a break down of one unit will not halt all operations.
How Can This be Achieved?

- Brand new approach is needed.
- A completely new breed of machinery is needed.
Current State

- No autonomous tractors at all.
- All approaches are tractor centric. Auto-steer and visual steer is currently on the market.
- Implements are passively dragged behind – they crab if they wish! As such crop location is undesirable.
- These machines can never be trusted to go over the growing crop again.
- Centralized power – centralized control.
Our Approach

• Implement centric
• Precision machinery
• Precision sensing
• Precision guidance

Through the implementation of practical control systems.
Our Approach...

• Tractors job changes from prime mover to **pilot vehicle**. It has no capacity to pull, but it has all the intelligence to guide (not to pull) the implement.

• In our case, the implement is the seeding implement. The most important (ground breaking) of all steps.

• The implement is a sophisticated design and is equipped with advanced controls.

• It can **steer**, **propel**, **guide** seeding tines, **lift** and **lower** ploughs, has a train of precision sensors.
Our System – Pilot Vehicle
Pilot Vehicle Sensors

- Steering sensor
- Wheel encoders
- Twin 2cm accuracy GPS running at 10 Hz.
- IMU
- Laser Range Finder – to detect obstacles
Steering Automation
Pilot Vehicle Operation
Our System – Seeding Implement
Seeding Implement Sensors

- Wheel encoders
- Tractor-seeder alignment sensor
- Tractor-seeder hitch point tension sensor
- Seeder Steering sensor
- Seeding tine position sensor
Seeding Implement Actuators
Seeder Steering System
Seeding Ploughs
Seeding Ploughs
Seeding Plough Operation

Individual fertilizer and seed row metering
Seeding Tine Adjustment
Software
Safety Subsystem

- Software crashes (Halt through hardware watchdog)
- Joystick controller auto off (manual mode).
- Joystick controller out of range of remote PC (manual mode).
- Base station out of range of tractor (manual mode).
- Expanding path offset and orientation off set (manual mode).
- Trespassing (manual mode).
- Network failure (Halt).
Control Systems

- Tractor path tracking using both path offset and path misalignment. No curvature error used.
- Seeder path tracking controller. Identical algorithm, except fixed body coordinate frame and no curvature
- Low level controllers
  - Force control of seeder wheel (note rigid couplings)
  - Position control of tractor and seeder steering.
  - Tractor wheel speed control
  - Seeder tine position adjustment control
  - Seeding plough lift control (ON/OFF).
Force Controlled Seeder Drive

Force Sensor Data <11-11-2011 at 11.24 am – Balaklava, South Australia>

Set point 0.3 volts = 200 N
A Typical Commanded Path
Field Operation

Go to www.youtube.com/UNSWMechatronics and then watch the Autonomous Seeder.
Its Accuracy
Camera Mounts
Accuracy Videos – Tractor Accuracy

- Included in the Youtube video
Accuracy Videos – Seeder Accuracy

• Included in the YouTube video.
Current State of the Project

• Invention has been patented.
• Control systems and software remain a trade secret component.
• Currently at Patent to Commercialization stage.
• Tractor steering hardware needs improvement.
• Speed adjustment through terrain roughness estimation via laser measurements.
• Advanced controllers for speed and accuracy improvements.
Those who help

- Mr. Stephen Kuhle
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- Mr. Russell Overhaul
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- Mr. Greg Glasgow (EMAI Menangle)