Automated camera-based crop monitoring and site-specific irrigation control systems

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NCEA’s automation research

- Machine vision, automation, robotics
- Low cost machine guidance
- Precision monitoring tools
Site-specific irrigation

- Can be over 200% variation in irrigation requirements: soil water holding capacity, elevation
- Variable-rate irrigation (VRI) hardware and variability mapping can be used

Dairy pasture in Tasmania: Horticulture field in Kalbar:
VRI research

- Research trials in horticulture, corn, pasture and cotton in Australia, New Zealand and USA
- Inputs include soil type, soil moisture, temperature, crop growth

IRTs in Texas: Cameras in QLD:
Commercial VRI use

- Cost about $1500/ha – includes VRI hardware, GPS, software, remote access
- Generally 0-20% yield increase or water reduction reported in literature
- Generally used for avoiding roads
- Only 10% of VRI purchased still used
VRI hardware

- Solenoid valve on each dropper
- Zones controlled with pulse width modulation and speed control to adjust flow rate
- Valley, Lindsay Zimmatic, Reinke, Trimble
Prescription map development

- For centre pivots, field divided into 1° sectors and zones along machine
- Original VRI systems needed manual entry of irrigation volume into individual zones
- Now polygons define zones
Prescription map development

- Field map imported into data management software e.g. PCT, SST

Original map:  

VRI map:
Prescription map development

- Zone-by-zone editing of prescription map

Zone prescription input:  VRI map:
Prescription map development

- User draws on polygon to define zones
Upload map to VRI system

- Remote access, radio or manual upload

Valley VRI map upload:
Monitoring - soil

NW_block_vert
ECa (mS/m)

- 325 - 425
- 264 - 324
- 227 - 263
- 204 - 226
- 191 - 203
- 182 - 190
- 169 - 181
- 146 - 168
- 109 - 145
- 47 - 108

SW_block_vert
ECa (mS/m)

- 194 - 233
- 170 - 193
- 156 - 169
- 148 - 155
- 143 - 147
- 140 - 142
- 135 - 139
- 127 - 134
- 112 - 126
- 88 - 111

SE_block_vertical
ECa (mS/m)

- 263 - 291
- 242 - 262
- 226 - 241
- 214 - 225
- 197 - 213
- 176 - 196
- 147 - 175
- 108 - 146
- 55 - 107
Monitoring – machine imagery

Smartphone camera

Height from quad bike sensor

Canopy cover from cameras

0 Height (mm) 250
VRI research

- CPLM VRI is historical map based
- Developing automated control strategies for timing and volume

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1. Sensors
   - fixed sensors
   - historical maps
   - on-the-go sensors

2. Control strategy
   - convert data to irrigation application
   - model-based control needs calibration with infield data

3. Real-time irrigation adjustment
   - actuators to apply irrigation

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Surface irrigation system

Overhead irrigation system
Irrigation control strategies

- Sensor-based control
  - Soil moisture status estimation using soil, temperature and/or reflectance sensors

- Model-based control:
  - A calibrated crop model simulates and predicts the next required irrigation, i.e. volumes and timings
    - according to evolving crop/soil/weather input
    - separately for all cells/zones
    - can choose alternative end-of-season predicted targets
  - Potentially higher yields than sensor-based control
Simulation of sensor-based control

1. EM38 map imported into VARiwise
2. Plant available water content map
3. Centre pivot uniformity can be imported
4. Control options
   A. Fixed irrigation schedule
      Irrigation is applied according to user-specified dates and amounts
   B. Soil moisture deficit-triggered irrigation
   C. Adaptive control

<table>
<thead>
<tr>
<th>Sensor location</th>
<th>Variability in machine uniformity</th>
<th>Yield (bales/ha)</th>
<th>Irrigation water use efficiency (bales/ML)</th>
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</thead>
<tbody>
<tr>
<td>Point 1</td>
<td>Low</td>
<td>7.0</td>
<td>0.7</td>
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<tr>
<td></td>
<td>High</td>
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<td>0.9</td>
</tr>
</tbody>
</table>
Control system implementation on centre pivot

Real-time camera-based plant sensing to update irrigation:
Conclusions

- Framework developed for data processing at a range of spatial resolutions

Next steps:
- Link control strategy output with commercial VRI system for cotton and dairy irrigation sites
- Online data management and processing for cotton and dairy data and control
- Evaluation of control strategies at all sites over next two years
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