e-Agri: Integrating Sensors & Electronic Engineering to Deliver Networked, Low-Cost, Smart Agriculture

Prof Bruce Grieve, e-Agri Sensors Centre
Electrical & Electronic Engineer, University of Manchester (UK)

IoT Vertical and Topical Summit for Agriculture
15:00, 8th May 2018, Tuscany, Italy

www.manchester.ac.uk/eee/e-agri
The University of Manchester

• Largest university in the UK: > 40,000 students
• > 10,000 international students, > 5,000 UK students from non-traditional backgrounds
• More subjects than any other UK institution
• 10,500 staff, > 5,500 academic and research staff
• Turnover > £1B (~US$ 1.6B)
• UK’s largest alumni: > Over 150,000 alumni living around the world
The e-Agri concept is unique as it seeks to inform the electronics & IT community of the distinctive needs of modern agronomy & food science…

... So that they can **fundamentally** engineer new systems and “e-” devices for reducing waste, increasing yields and improving nutrition.
Traditional View of Agriculture???
Why are Sensors and IT Important to the Agri-Food Sector

- Market Forces
- Technology
- Legislative & Regulatory
- City Planning

Ubiquitous!
Integrated Reality: No Single Solution

smart sensing & monitoring

BIG DATA

smart analysis & planning

smart control

Image courtesy of S. Wolfert

N8 AgriFood – www.n8agrifood.ac.uk

One Network, Many Solutions
Agri-Tech Involves the Whole Supply Chain and Beyond

Smart Farming

Tracking/Tracing

Smart Logistics

Domestic IoT

Health

Fitness/Wellbeing

Image courtesy of S. Wolfert

Source: Hisense.com

Smart Farming

Tracking/Tracing

Smart Logistics

Domestic IoT

Health

Fitness/Wellbeing

Image courtesy of S. Wolfert
Redefining Industry Boundaries (1/2)

(according to Porter and Heppelmann, Harvard Business Review, 2014)

1. Product
2. Smart Product
3. Smart, connected product

Image courtesy of S. Wolfert
Redefining Industry Boundaries (2/2)

5. System of systems

weather maps
weather forecasts
weather data application
rain, humidity, temperature sensors

farm equipment system
combine harvesters
tillers
planters

System

irrigation application
irrigation nodes
field sensors
seed optimization application
seed database
farm performance database

image courtesy of S. Wolfert

4. Product system

Your company
Kverneland
Maglis
365FarmNet
farmpilot
Akkerweb
LELY

N8 AgriFood – www.n8agrifood.ac.uk
One Network, Many Solutions
Restructuring of Agri-Tech World to Address New Data Reality

AgBusiness
- Monsanto
- Cargill
- Syngenta
...

Farming
- Cooperatives
- Open Ag Data Alliance
...

Ag Tech
- John Deere
- Trimble
- Precision planting
...

Tech Companies
- Google
- IBM
- Intel
...

Tech Start-ups

Data Start-ups

Venture Capital
- Anterra
- Founders Fund
- Kleiner Perkins
...

Farm
TRL Positioning of e-Agri Centre

- Business or Technology inspired idea for sustainable agriculture / food supply
- Take ideas to field trials & early business models = Stage Gate TRLs
- Not ‘blue skies’ – some basic concepts developed
- De-risked for licensing or spin-out
N8 AgriFood: Joined up thinking across the whole supply chain

www.n8agrifood.ac.uk

UK Universities of: Durham, Lancaster, Leeds, Liverpool, Manchester, Newcastle, Sheffield & York
Agri-IoT: An Enabler for Sensors

A First Exemplar: From Dishwashers to Field Run-Off Mapping and Flood Prevention
Turbidity Sensors in Water Course

- Turbidity (water haze) acts as a measure of field run-off into water course.
  1. Used to map the environmental impact of run-off from fields, due to incorrect land and soil management
  2. As a real-time surrogate for pesticide concentration in waters entering treatment works (the pesticides are assumed to be sorbed to the particulate material)

- Proprietary portable sensors c.£3-£5K ea
- Accurate but expensive – so only small numbers...
Dishwasher Sensors <US$10

- Regulatory controls on whitegoods – Dishwashers all have simple turbidity sensors
- 0-1000 NTU => poor sensitivity at 0-50 NTU
  1. Signal averaging
  2. Extend path length
- Many units allows for a network
- Many sensors =>
  - Real-time map and correlate turbidity events
  - Compensate for weaknesses in individual sensors, e.g. particle size or shape sensitivity, losses of signals, etc.
  - ‘Wake-up’ down stream sensors for rapid data collection on demand, e.g. flood event
‘Radio 4 LW Band’

**LOW BANDWIDTH**

**Systems Architecture**

- **Sensor Module**
  - Microchip µC
  - RN2483 Transceiver

- **Gateway Module**
  - LoRaWAN Protocol 848 MHz
  - Pi 3
  - Semtech SX1301 Concentrator

**Network Components**

- **Server**
  - Gateway Bridge
  - Network Server
  - Database Server
  - Application Server

- **Web Portal**

**Functionality**

- IoT ready - LoRaWan™
- Fully customized PCB
- Long battery life, ~2 years
- 30 nodes - providing 24x7 turbidity monitoring
- Periodic data transmission

_N8 AgriFood – www.n8agrifood.ac.uk_
_One Network, Many Solutions_
Sensor Module Components

- Antenna
- Sensor PCB
- Turbidity Sensor Probe
- LoRa-WAN Module
- PIC18
- Real-Time Clock
Less than 5 minutes to Install a Node
SYield: Learning from the Customer

Mimic-Sensor Platform for Detection of Fungal Disease

Sensors for protecting crop YIELD
Design of sensor surface with features to trick spore into germination
- thigmotropism?
- pH gradient?
- nutrient availability?
- light?
- others?

Physical detection of germ-tube
- e.g. electrical capacitance, stress, optical, volatiles, etc

Housing: Real-time sensor node
- Commercial in-field spore trap + Sensor array + Wireless network
- Each node can then be expanded into a multiple pathogen / pest sensor system

From Septoria in Winter Wheat Concept to…
... to early adoption reality, *Sclerotinia* in Oil Seed Rape

**Disease cycle for sclerotinia**

- **Wind borne ascospores**
- **Petal infection**
- **Infection spreads from cast petals to stem**
- **Apothecia**
- **Germinated sclerotia**
- **Sclerotia form in stem**

**Can germinate on plants but not infect without exogenous source of nutrients**

**Can penetrate using a variety of mechanisms**

**Oxalic acid is required for pathogenicity**

**Sclerotia can survive up to 8 years in the soil**
○ Oxalic acid, produced by the incubating spores, can be detected using enzyme technology which is similar to that in blood glucose sensors.

○ Oxalate oxidase catalyses the reaction:
  \[ \text{HOOC-COOH} + \text{O}_2 \rightarrow 2\text{CO}_2 + \text{H}_2\text{O}_2 \]

○ Horseradish peroxidase catalyses the reaction:
  \[ \text{H}_2\text{O}_2 \rightarrow \text{O}_2 + 2\text{H}^+ + 2e^- \]

○ Electrons are picked up by the sensor electrodes, generating current.

○ Signal converted into risk prediction.
Integrated Farm Package: 24/7 Cover

In-Field Sensor Units

Electronic Interfacing Company

Wireless Sensor Node

Syngenta
Crop Protection Company

Service Provider (SSC)

Weather Data

Web Information Company

Data Depiction and Mapping Service

Central Database

Commercial Farm Company

Biochemistry Company

Sample System Company

Air sample
2018 B&M Gates Foundation: 3D Printed Biomimetic Sensors

- Platform opportunities: *but originally pre-Agri-IoT*
- Opportunities for expansion into new families of fungal pathogens and their hosts e.g. rusts in wheat, etc.
- Development of not just the sensor biology but fully integrated metadata & information flow.

- Can the concept of a mimic sensor be translated under the soil?
- Use additive whole-cell printing to grow biomimetic surfaces for viruses (e.g. CBSD, Avian Flu – Pirbright)?
New Disruptive Technologies need new:

- methods of identify real not perceived needs
- business models and supply chain interrelationships

UK Global Food Security Programme: ‘IKnowFood’ - https://iknowfood.org/ (Liverpool, York & Manchester)

- Launched Oct 2016, 4 years, £3.2M

An opportunity to address the issues