Challenges and Opportunities of Sensors and Intelligent Systems for Food Chain

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Food Chain- A complex value chain

Production Practices

Harvest

Post-harvest

Seed

Fruit

Consumer

Ref: MS office clip arts-online

Sustainability

- Resources
  - Environment
  - Water, air, soil
  - Energy
- Food
  - Quantity
  - Quality
- Economics

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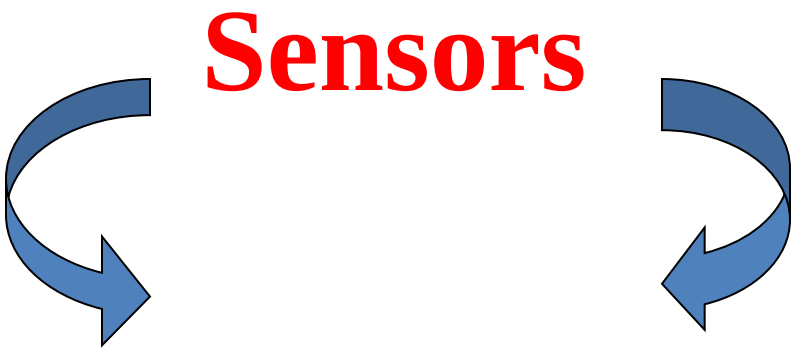
Sensors



Intelligent Information Processing System

Intelligent Systems

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Agricultural Evolution- Productivity

- Land grant university
- Mechanization
  - One of the greatest achievements of 20th century
- Genetics
  - Breeding
- Chemical application
  - Pesticide
  - Diseases

Precision Farming

- Soil System and practices
- GPS and sensor technology
- Remote Sensing (Satelliete Images)
- Artificial intelligence Technology
- GPS
  - Yield map
- Soil nutrient determination
- Variable rate application
- Panigrahi group
  - Image and non-image information
  - Leaf Nitrogen prediction
    - *Biosystems Engg 95(3) 2006*
  - Residual soil nitrate prediction- Imaging and non-imaging parameter
    - *Biosystems Engg. 110(1) 2011*

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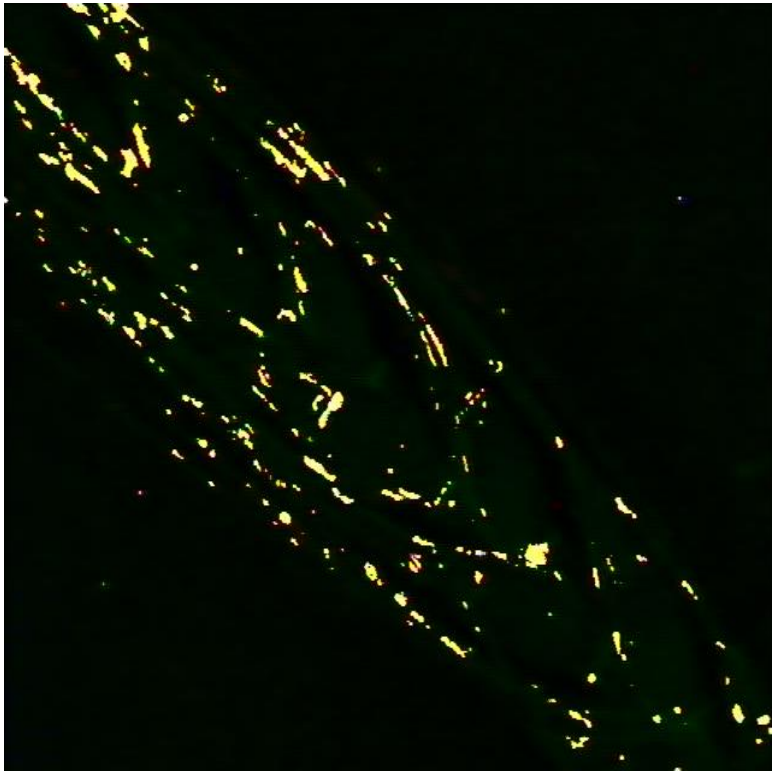
Chemical Application

- Plant Diseases
  - Chemical (pesticide)
- Sprayers
- Foliar Microclimate
- Drift
  - Spray sensitive card
- Aerial spraying

Objective Spray Coverage Evaluation System for Wheat

(a) Wheat Head Image



(b) Spray Image

Plant Disease

- Variable rate application
- Spraying
  - Right amount and right spot
- Plant Diseases prediction (Panigrahi group)
  - Intelligent modeling
  - From foliage, weather parameters

Portable Plant Health Monitoring Systems

- Critical
  - During growth stage
  - Conventional methods
    - disadvantages
- Portable and non-contact system
- Chlorophyll
- Leaf nitrate

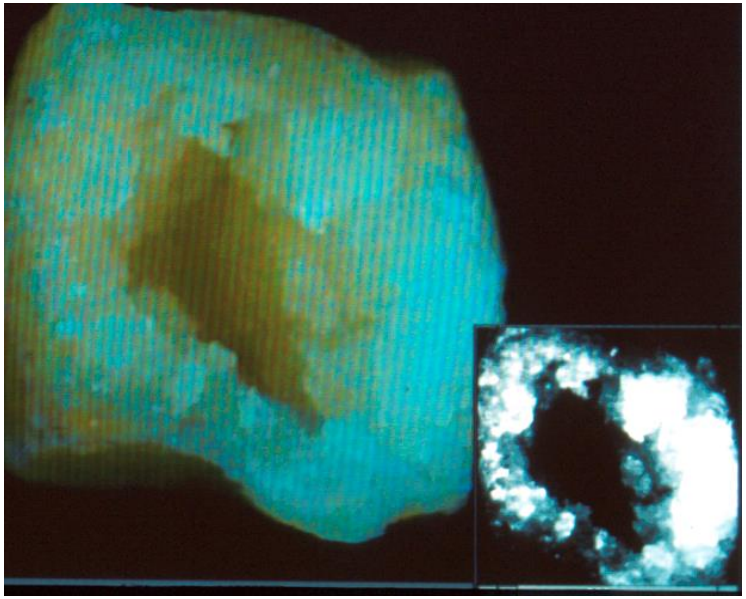
On-the-go field scale quality sensor

- Challenges
  - Dust
  - Temperature
  - Vibration
- Panigrahi group
  - Wheat protein
  - Sugar content for sugarbeet
  - Patents

Sensor Technologies for Post-harvest quality control and inspection

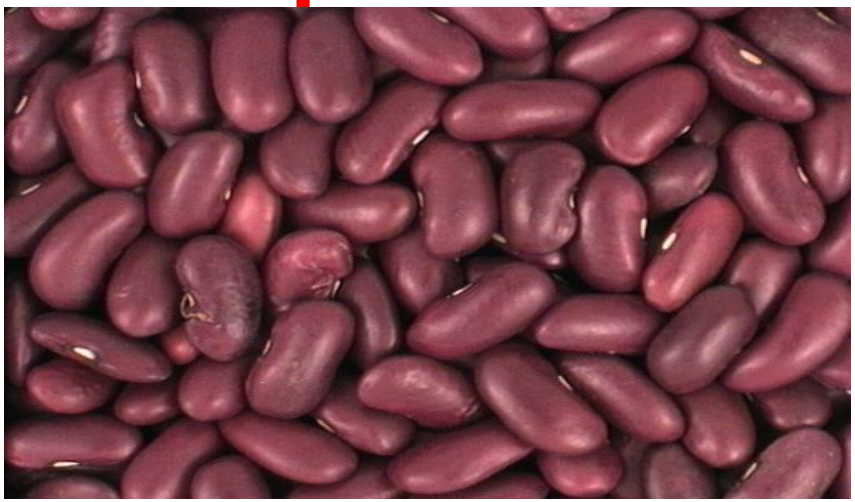
- Computer vision
  - Color classification

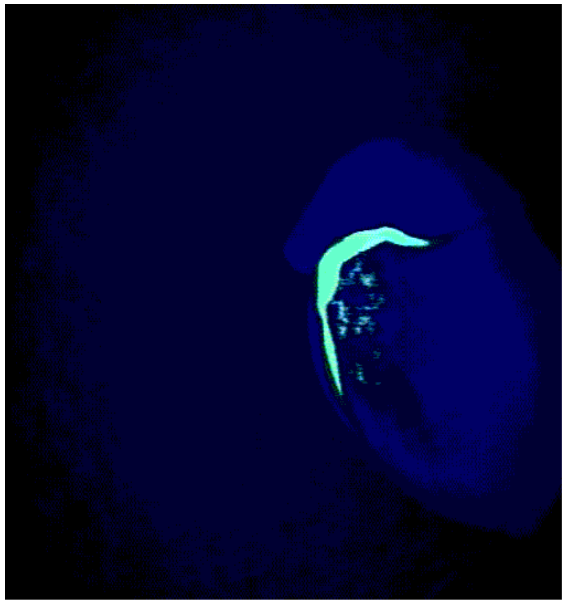
- Internal texture
  - Tactile sensing and neural networks

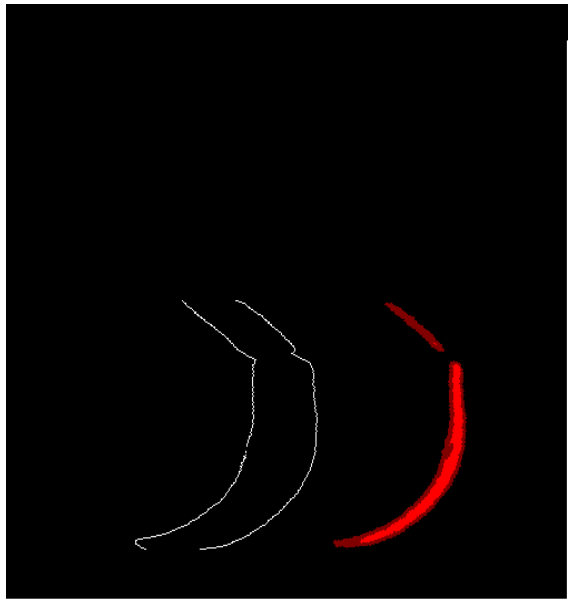


Sensor Technologies for Post-harvest quality control and inspection

- Computer vision
  - Edible quality evaluation
  - International marketing





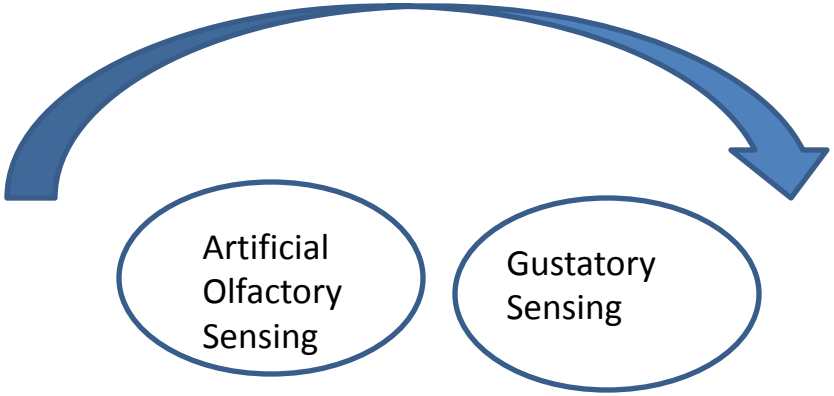


Sensor Technologies for Post-harvest quality control and inspection

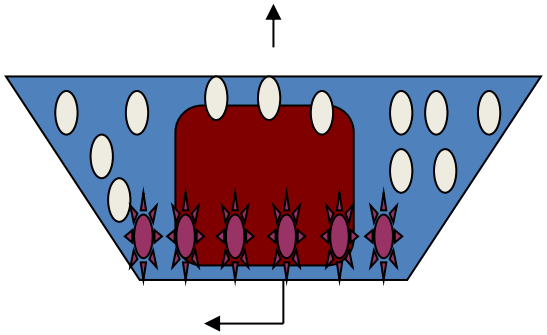
An electro-mechanical prototype designed and built in-house for high speed automated evaluation of edible beans using computer vision technology.

Intelligent Quality Sensors for Safe Food Products

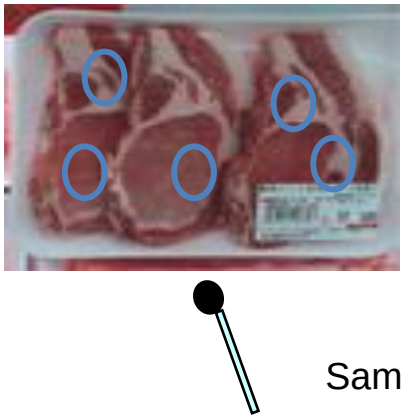
Hypothesis : Gaseous and liquid metabolites of pathogens growing on food matrix can be sensed.



Accumulated headspace



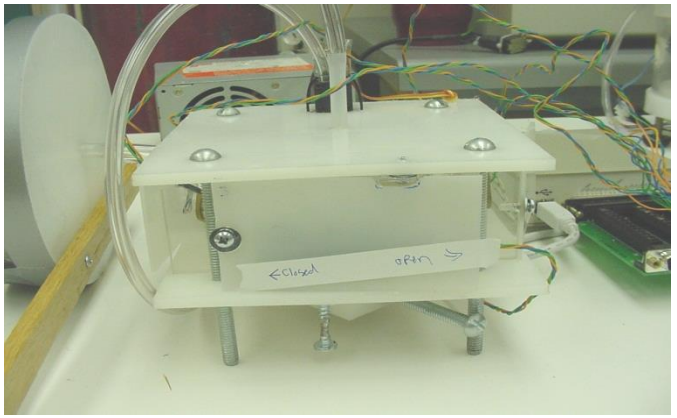
Accumulated liquid

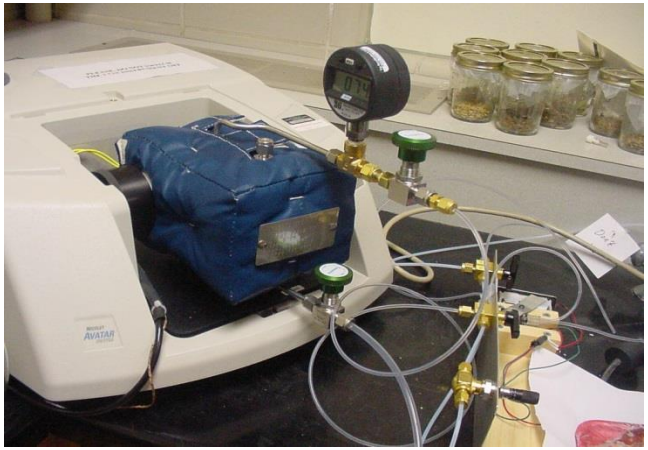


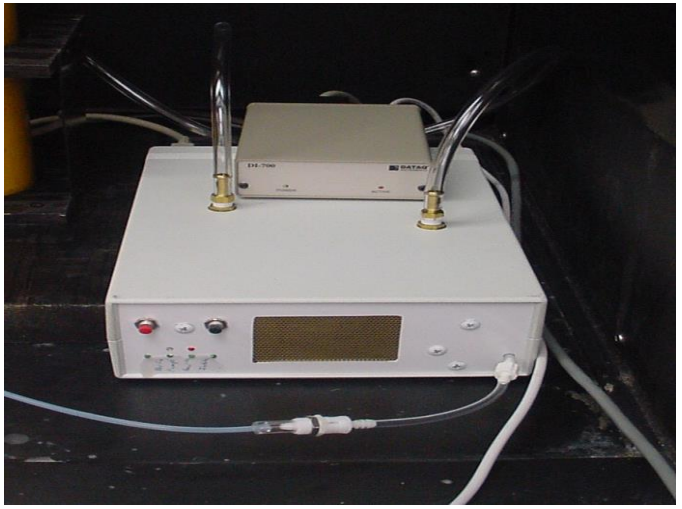
Independent of sampling location

Different sensor technologies

Cyranose

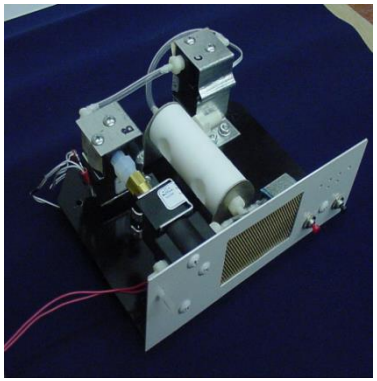


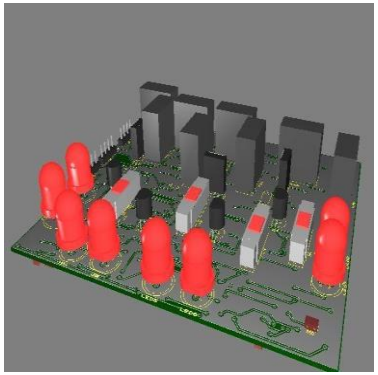


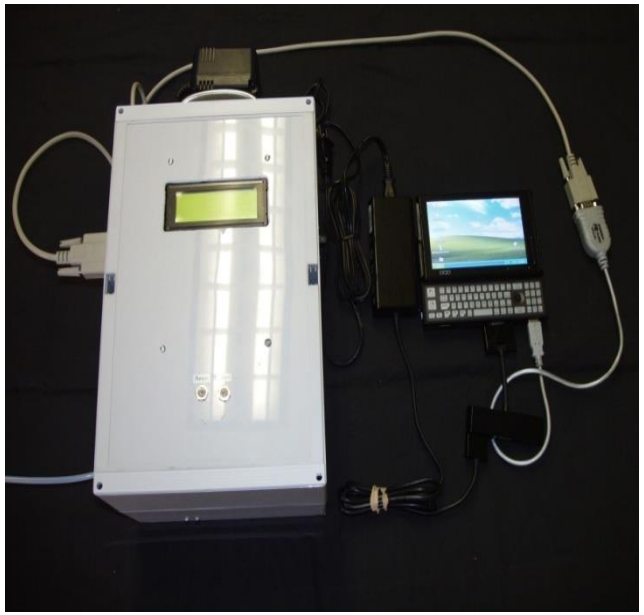


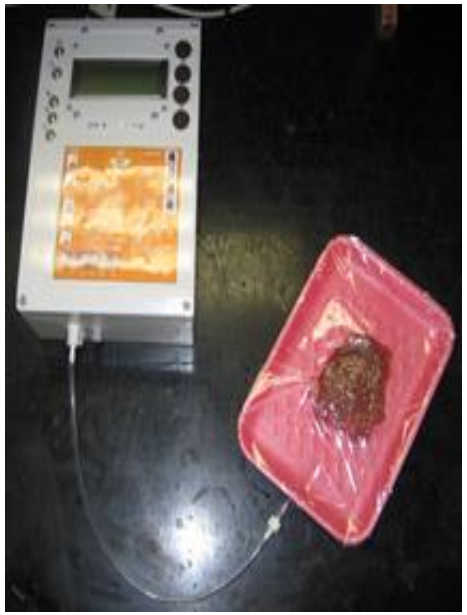
Intelligent Artificial Nose Development (IAN)

Multiple approaches





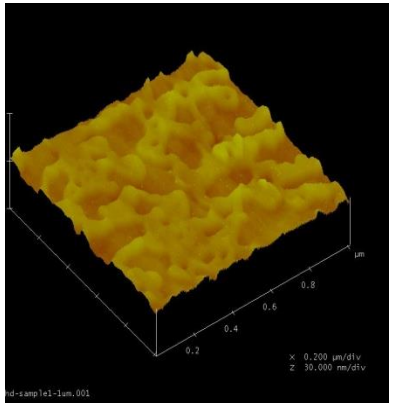


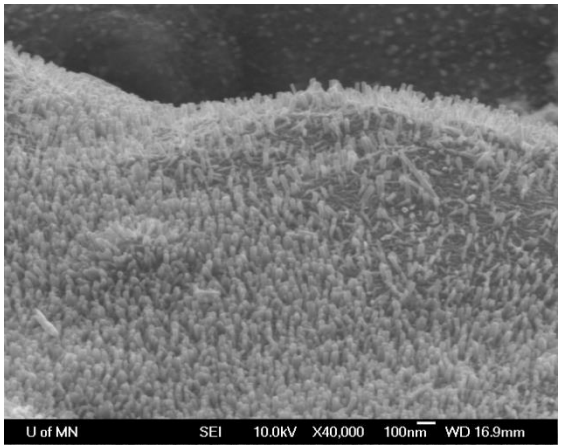


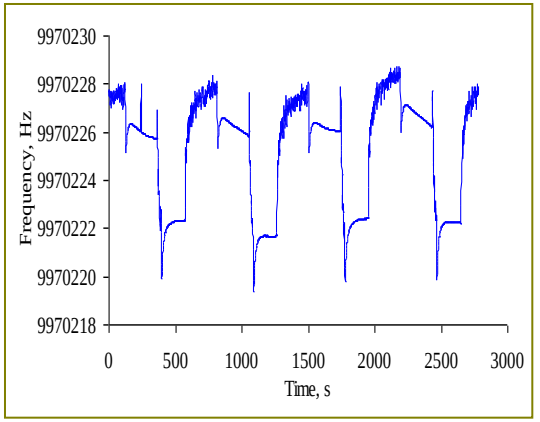
Evaluation of Nano-structured Sensing Material for Detection of VOCS – associated with Pathogen Activities

- Hybrid Approaches
  - Array detectors + Indicator Compound detector
- Porphyrin
- Conducting polymer
- Metal-oxide
- Biomietic odor binding protein
- Olfactory receptor-based sensor

- *Selected*
- *Biosensors and Bioelectronics 26(7) 2011;3103-3109*
- *Sensors and Actuators B 2011; 153(1): 1-10.*
- *Materials Science and Engineering 32(6), 2012:1307-1313.*
- *Sensors and Actuators B 2011; 155(1):8-18.*
- *Biosystems E*







Electronic nose for grain quality

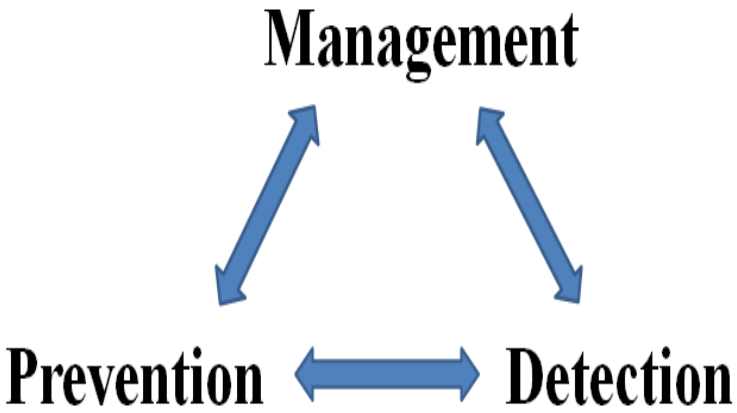
- Panigrahi's group
- Fusarium infected barley
- Accpetable or non-acceptable
- Ergosterol content
- 86% accuracy
- *LWT 40(2007) 1815-1825*

Water- also part of food

- Contaminated water can also contaminate food
- Induced effect
- Arsenic
  - Geophysical
  - chemical
  - Connected issues
  - Intensive chemical application
- Role of sensors

A system's Approach

- Sustainable Solution using Appropriate Technological Development and Innovation (SWADIN)
- Reverse innovation
- Water-linked health and wellness



Lessons Learned

- Sensor technology has tremendous potential
- User and market readiness – for Agricultural and food sector
- User (stakeholder's) behavior and perception, Socio-economics
- Issues are connected
  - *Earth from space* – Nova- PBS program
  - A connectedness – beyond imagination
  - Chaos leading to order
  - Role of 120 satellites – sensors
  - Intelligent form

Food-water-energy nexus

- Interdependencies
- Climate change
- Abiotic and biotic factors
- Soil health – a dynamic system
- Microbial ecology
  - Metagenomics
  - Food safety
  - Human and animal health
- Eco-system perspective
  - Soil-microbe
  - Plant-microbe
  - Pathogen ecology
- Questions
  - How climate change (microscale) affect microbial and pathogen ecology?
  - How a certain event (rainfall) affect pathogen transfer to crops (fruits)?
  - How long the pathogen survive on the surface of a fruit?
  - How can we determine or sense the dynamics of conditions under the soil?

Trend

- Connected economy
  - local, national and global
- One health initiative
  - www.onehealthiniative.com
  - Plant, animal and human
  - Infection- 70% vector borne
  - Plant diseases
- Consumer awareness
  - Fresh fruits and vegetables
  - Ready to eat with minimal processing
  - Organic food and implication
- Food consumption trend
  - Animal product consumption increasing in India and China
  - Economical growth
- Policy and regulations

Role of sensor and sensing technology

- *Food, Energy, and Water: Transformative Research Opportunities in the mathematical and physical Science- July 2014*
- Multi-scale sensing
  - Macro to micro
  - Satellite sensing to ground level location specific sensing
  - Multiple sensors with redundancy
  - Sensor fusion
  - Intelligence
  - Post- analytics and Meta data
- Internet of things - IOT
  - MEMS level technology platform
  - Cost effective and small foot print
  - Connectedness
  - Economy of scale
- Intelligent Informatics
  - Deep learning
  - Analytics

Considerations

- **System and sub-system level**
  - grain
  - Tree fruit
  - Vegetable
  - Animal system
    - Meat
    - Dairy
    - Poultry
  - Urban Agriculture
    - Controlled environment
    - Hydroponics
- Innovation
- Real-time decision or decision support systems
- Hierarchy of sensor/sensing system as different critical points in the value chain
  - First line of screening system
    - Cost-effective; acceptable accuracy
  - Gold standard laboratory scale sensing system
    - Costly, but highly accurate