Robotics and Automation for Agriculture

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Sanjiv Singh

Research Professor
Carnegie Mellon
THE ROBOTICS INSTITUTE

CEO
NEAR EARTH
AUTONOMY

Collaborators: Marcel Bergerman, Steve Nuske, George Kantor, David Wettergreen

Field Robotics

- Outside the built environment
- Dealing with Unknown, Uncertain, Rugged, Dynamic environments.

- Conditions can not be controlled (lighting, vegetation)
- Operation in all weather conditions (precipitation, temperature range, smoke, dust)
- Terrain can be varied and dynamic with time and location
- Scale of operation may be in tens or hundred of kilometers

Field Robotics @ Carnegie Mellon University

- Field Robotics at CMU started 1984
- Now large % of Robotics Institute involved in Field Robotics related topics: 70-100 faculty, staff, students.
- Serves as focal point for researchers in various disciplines: vision, planning, control, fault tolerance. Recent collaborations with geologists and astrobiologists

- Distinguishing Aspect: Have built a large number of robots in house and put them into extended use in demanding missions. Many technologies in the process of being commercialized

Historical Projects: Motivated by Hazard

New Emphasis: Commerce & Security

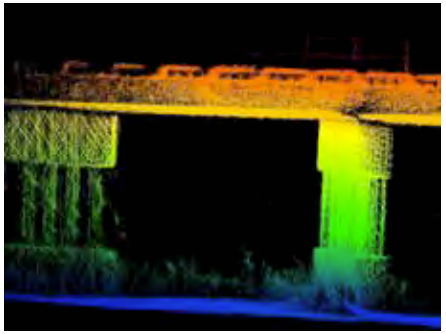
Paint Stripping

Mowing

Patrolling

Gas Line Repair

Bridge Inspection



Earthmoving

Warehousing

Farm Automation

Automation in Specialty Crops

Apple

Nursery Trees

Grapes

Strawberries

USDA Specialty Crop Research Initiative

Main Technical Themes

Crop Intelligence

Plant stress & disease detection
Insect monitoring
Crop load scouting
Caliper measurement
Information management

Automation

Reconfigurable mobility
Accurate positioning
Augmented harvesting

Means to get better information to growers:

- faster detection of pests/disease
- better yield prediction
- integrated management of crops

Devices that to help growers become more efficient:

- reduced labor
- faster operations

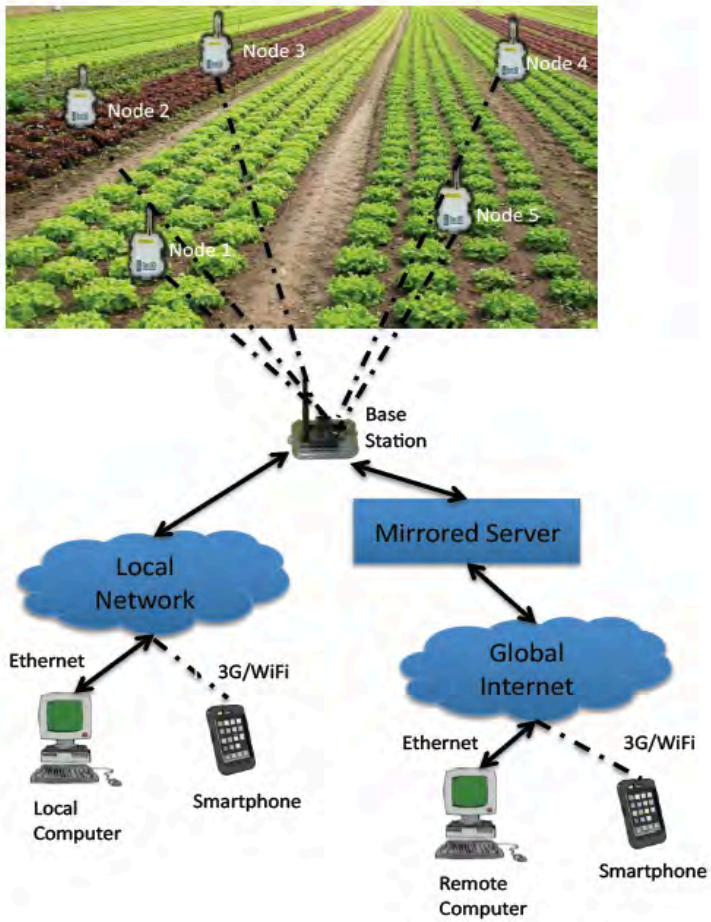
Outline

- Platforms
  - Sensor Networks
  - Ground Robots
  - Air Robots
- Derived Measurements from Remote Sensing
- Provocative Future Statement
- Take Away

Wireless Sensor Networks

- Basic Concept:
  - Robust, low-power, low-cost nodes that can be attached to sensors and easily deployed in various environments
  - Great for macro measurements (10-1000 sq. meters).

- Three primary components
  - **Sensors:** Devices that sense the environment (e.g., soil moisture)
  - **Nodes:** Inexpensive devices that read from sensors and transmit the data to a central basestation
  - **Basestation:** Used to configure nodes, and work with node sensor data



Example Sensors

soil moisture

temperature, RH

wind speed and direction

light

leaf wetness

rainfall

Ohio
Indiana
Kentucky
Virginia
North Carolina
South Carolina
Alabama
Georgia

Can be used for actuation too!

Platforms

- Best for deploying sensors that need measure at the micro-scale (sub-meter): Chlorophyll, plant stress, leaf area index.

Modified Electric Utility Vehicle

Imagers deployed: Laser Scanners, NDVI imagers, Color Cameras

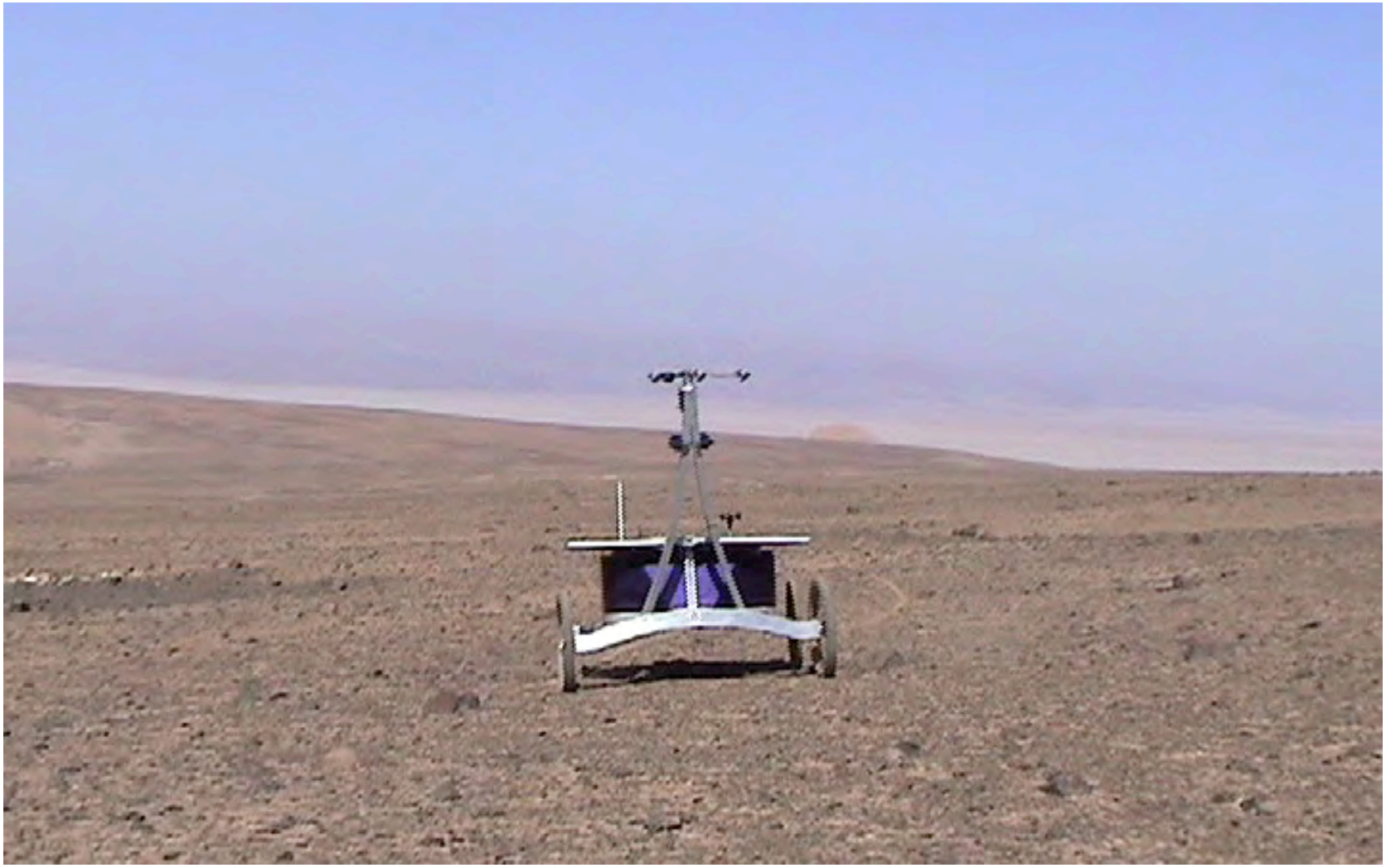
Custom vehicle for planetary exploration

Sensors deployed: Spectrometer, Fluorescence Imagers, Color Cameras

Platforms: Modified Commercial

Big advantage terms of reliability and cost to acquire/operate

Platforms: Customized



Could leverage mature technology developed for NASA platforms suited for bio-sampling

Scaling Effects for Autonomous Rotorcraft

Small

Rotor diameter: <1 m
Top Speed: 5 m/s
Useful Payload: <1 kg
Range: 1 km
Applications: Surveillance, Mapping

Medium

Rotor diameter: 3 m
Top Speed: 15 m/sec
Useful Payload: 30kg
Range:10 km
Applications: Recon, Survey

Large

Rotor diameter: 10 m
Top Speed: 50 m/sec
Useful Payload: 300-500kg
Range: 100 km
Applications: Transport, Casualty Evacuation

Field Survey with Small UAVs (no GPS)

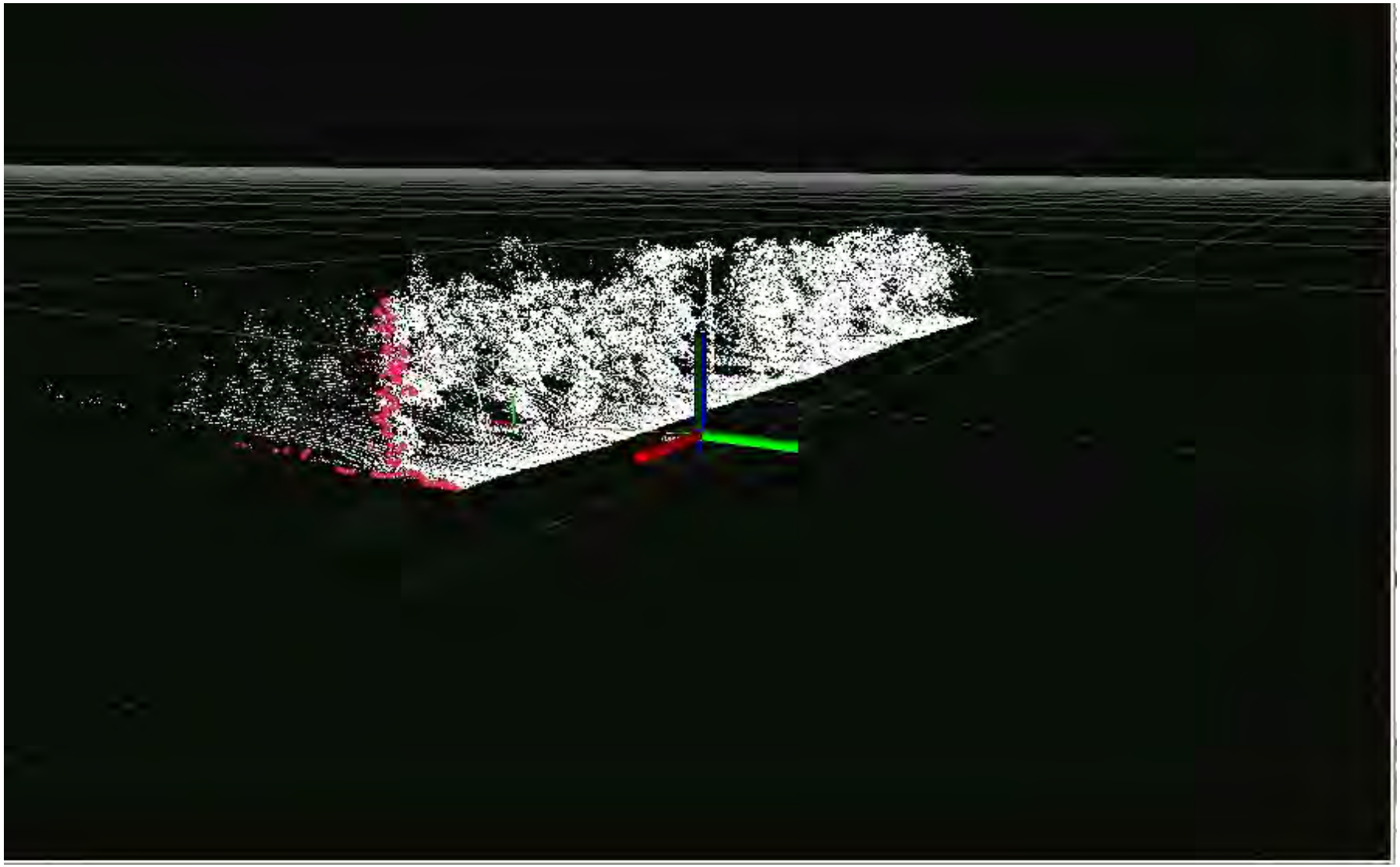
15 minutes with 1 kg payload

Extended Sampling with Medium Scale UAVs

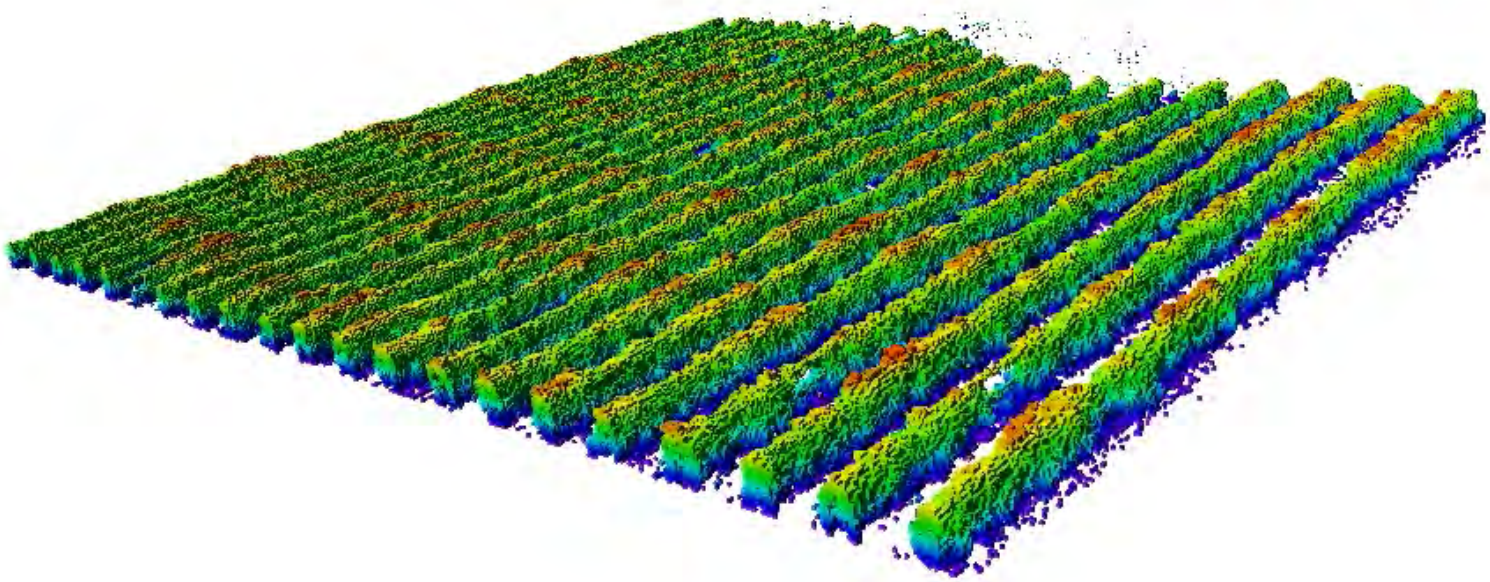
1-2 hours with 15 lb payload

Derived Measurements from Remote Sensing (2D)

Acquiring Data

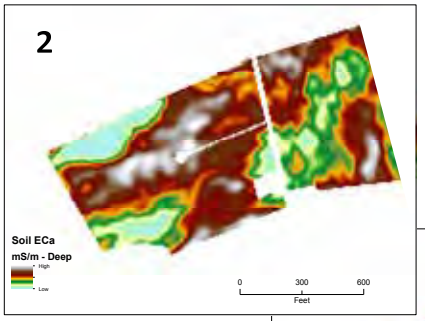


Three Dimensional Reconstruction

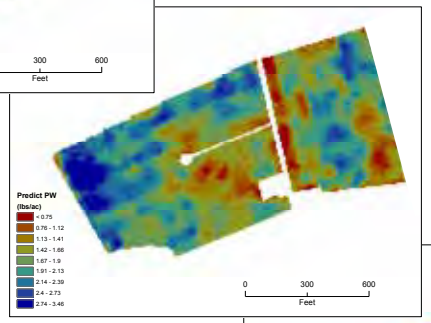


Derived Measurements from Remote Sensing (3D)

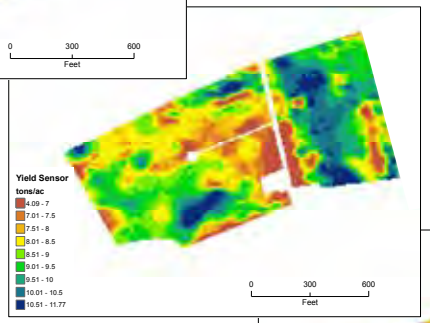
Integrated Sensing



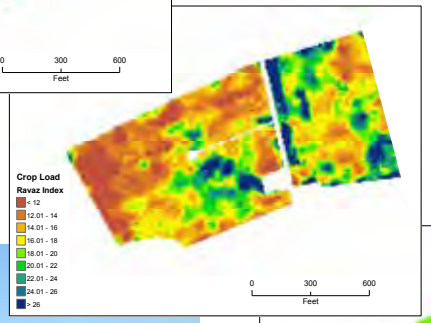
Soil (EC)



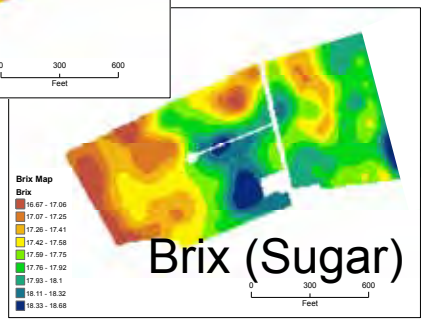
Canopy (NDVI->LAI)



Crop (Size/Weight)



Crop Load



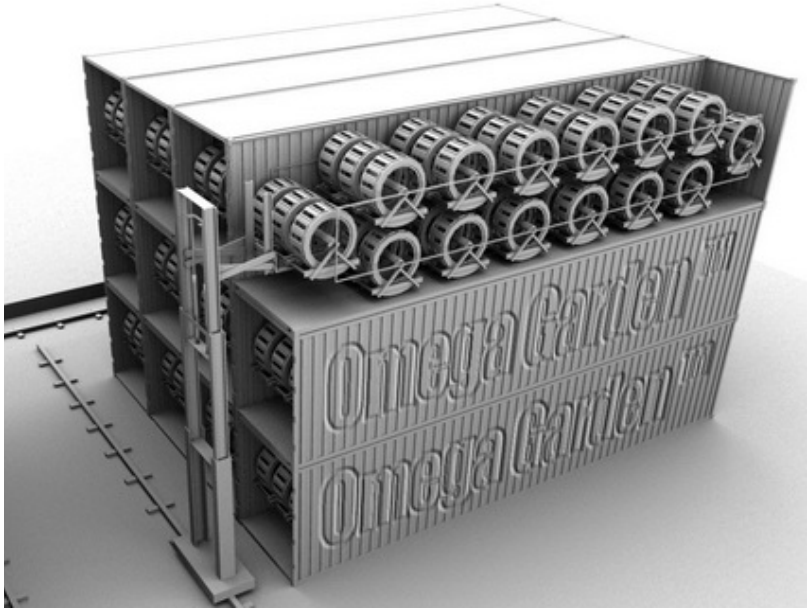
Brix (Sugar)

In the Future…

- Population expected to reach 9 Billion by 2050
- Need to change the way food is produced. We need:
  - Higher yield
  - Mitigation from disease, weather anomalies
  - Lower footprint
- Farming needs to move to more controlled setting
- Vertical Farming close to population centers with new methods of propagating, tending and harvesting needed

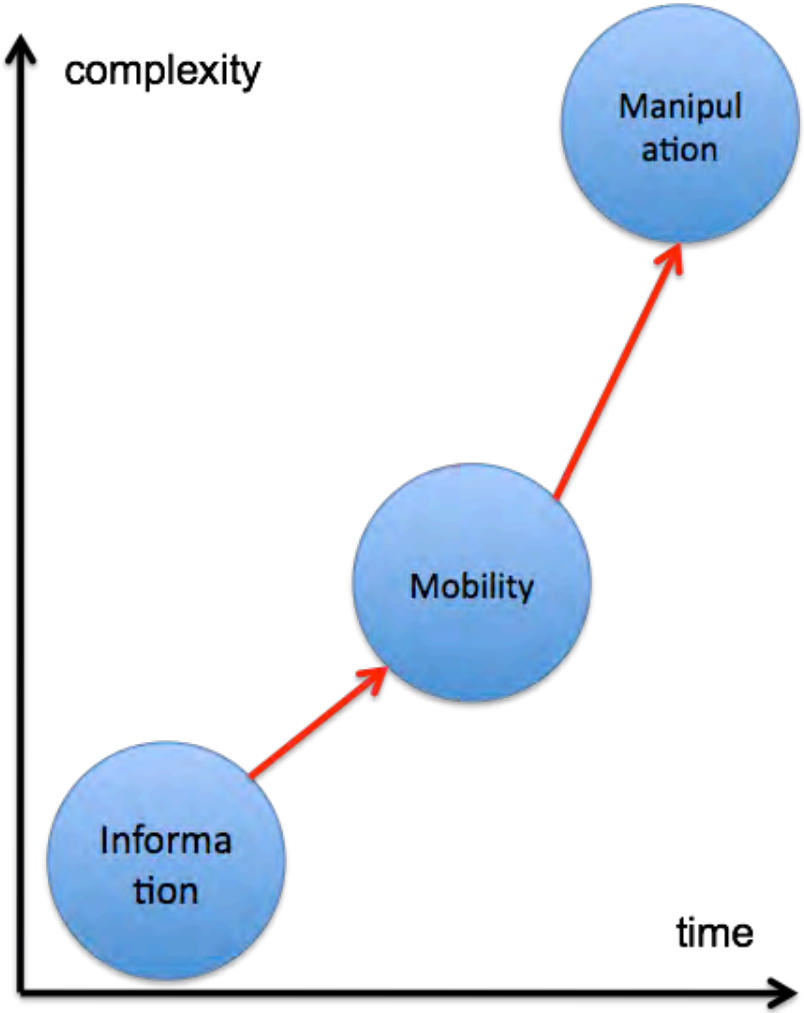
CHIVES
PEPPERS
BRUSSEL SPROUTS
TOMATOES
THYME
SPINACH
PEAS
LETTUCE
PEACHES
APPLES
CABBAGE
STRAWBERRIES
CHERRIES

Infrastructure can be minimized



What Automation can do for high-value Agriculture?

- Provide up to date high-resolution information
  - Crop yield
  - Plant growth
  - Plant stress/disease/ infestation
- Optimize simple tasks
  - Spraying, mowing, transportation
- Remove bottlenecks
  - Mechanize high-cost tasks such as thinning, pruning, harvesting



Thanks.