Machine Learning and Sensor Fusion for Precision Farming

Solmaz Hajmohammadi, Christopher Schardt, Noah Fahlgren, Arash Abbasi, Stefan Paulus
Food Insecurity

- Increase in population
  - 2.8 Billion more people to feed by 2050
- Increase in cost of labor, fertilizers, ...
- Decrease in total land
- Climate change
Baseline Projection for people at risk of hunger in 2010, 2025 and 2050

<table>
<thead>
<tr>
<th>Region</th>
<th>Projected Year</th>
<th>2010</th>
<th>2025</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>East Asia and Pacific</td>
<td></td>
<td>177</td>
<td>131</td>
<td>122</td>
</tr>
<tr>
<td>Europe and Central Asia</td>
<td></td>
<td>23</td>
<td>23</td>
<td>21</td>
</tr>
<tr>
<td>Latin America and the Caribbean</td>
<td></td>
<td>60</td>
<td>61</td>
<td>45</td>
</tr>
<tr>
<td>Middle East and North Africa</td>
<td></td>
<td>17</td>
<td>21</td>
<td>24</td>
</tr>
<tr>
<td>South Asia</td>
<td></td>
<td>318</td>
<td>310</td>
<td>235</td>
</tr>
<tr>
<td>Sub-Saharan Africa</td>
<td></td>
<td>240</td>
<td>275</td>
<td>268</td>
</tr>
<tr>
<td>Developing</td>
<td></td>
<td>835</td>
<td>821</td>
<td>716</td>
</tr>
<tr>
<td>Developed</td>
<td></td>
<td>49</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>World</td>
<td></td>
<td>884</td>
<td>870</td>
<td>766</td>
</tr>
</tbody>
</table>
Answer is...

Harvest Your Field Data
Artificial Intelligence (AI):
- The theory and development of computer systems able to perform tasks that normally require human intelligence.

Machine Learning (ML):
- ML is a type of AI that provides computers with the ability to learn without being explicitly programmed.

BIG DATA
Genetics

Irrigation

Soil

Climate

Increase Yield
Hardware Platforms
Field Scanalyzer System

- High Throughput Automated Field Phenotyping System
Sensors

PSII camera

Hyperspectral cameras

Laser scanner

IR

Stereo RGB
Color Coded 3D Data from Whole Field
Color Coded 3D Plants as They Grow
What can Machine Learning do?

- Autonomous Cars
- Classification
- Object Detection
- Stock Market Analysis
- Game Playing
- Search Engines
- Hand Writing, Speech, Face Recognition
- ...
What can Machine Learning do?

- Robot learning how to cook by watching YouTube
What can Machine Learning do?
LemnaGrid – Machine Learning

**New Sensor Data**

**Sensor Training Data**

**Image Analysis Configuration**

**Data Labeling** (Points of Interest, Diseases, Objects)

**Save to Database**

**Calculate Features**

**Save to Database**

**Classification Algorithm**

**Train and Evaluate** an Classification Algorithm

Support Vector Machine, Random Forest, Boosted Trees

**Classification Result**

**Color, Texture, Keypoints, Shape, Wavelengths, Vegetation Indices,...**
LemnaGrid – Machine Learning

- Easy to use machine learning workflow based on a single Image Analysis Configuration
- Classification on various sensor data, i.e. RGB, hyperspectral Imaging
### LemnaGrid - Machine Learning

#### Segmentation of 3D point clouds

<table>
<thead>
<tr>
<th>Boosted Tree Classification</th>
<th>Detected as a spike</th>
<th>Non-spike</th>
</tr>
</thead>
<tbody>
<tr>
<td>True Spike</td>
<td>0.994</td>
<td>0.0057</td>
</tr>
<tr>
<td>True Non-spike</td>
<td>0.0074</td>
<td>0.992</td>
</tr>
</tbody>
</table>

3D Laser Scanner Rothamsted Research

Original resolution (RN = 1, RH = 8)
Detecting Plant from Background

Noah Fahlgren, Arash Abbasi
Convolutional Neural Network

- Learn a feature hierarchy from pixels to classifier
- Each layer extracts features from the output of previous layer
- Train all layers jointly

Noah Fahlgren, Arash Abbasi
Convolutional Neural Network

Convolution + non linear rectifying

Deconvolution + non linear rectifying

Noah Fahlgren, Arash Abbasi
Convolutional Neural Network

Iterations ➔

Noah Fahlgren, Arash Abbasi
Any nontrivial machine learning algorithm needs high-quality dataset. This increases the demand for fusing machines, sensors, and crop models to produce a dataset with high structural and spatial details.
Sensor Fusion → Machine Learning

- Sensor fusion is a process of integrating data collected with different sensors at different spectral, spatial and temporal scale.

![Diagram showing sensor fusion and machine learning process]
Sensor Fusion $\rightarrow$ Machine Learning

- We produce a dataset with higher order information and knowledge content than could be achieved by assessing each sensor independently.
RGB and IR Fusion

RGB

IR

Overlaying IR & RGB

Fused data IR & RGB
RGB and IR Fusion

- RGB mask can be used to subtract the background from the plant in IR

- IR data can be used as 4\textsuperscript{th} channel for RGB data and used in a same ML algorithm
3D and RGB Fusion

- Pixel-level information using RGB and 3D fusion
3D and IR Fusion

- 3D and IR Fusion
IR + 3D Fusion from Whole Field

Observe the temperature increase along the path from 9am to 2pm
Conclusion

- Increased accuracy in target detection and recognition for machine learning algorithms.

- Sensor Fusion provides enhanced structural and spatial details, and corrects for reflectance complexity and provides higher level of calibration.
Thank you...