Dynamic High-Precision Field Shape Generation via Combine GPS Tracks

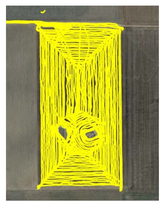
Yaguang Zhang[1], Andrew Balmos[1], James Krogmeier[1], Dennis Buckmaster[2]

[1]School of Electrical and Computer Engineering and [2]School of Agricultural and Biological Engineering, Purdue University, West Lafayette, IN 47907

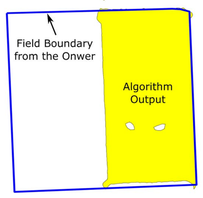
Motivation

- Field boundaries are currently troublesome to generate and thus usually outdated
- What exact parts have yielded valid product is necessary for comprehensive field analyses
- Up-to-date knowledge of field shapes with higher precision can help farmers make better logistic decisions

(a) Field boundary from the owner



(b) Combine tracks involved



(c) Field boundary vs. algorithm output

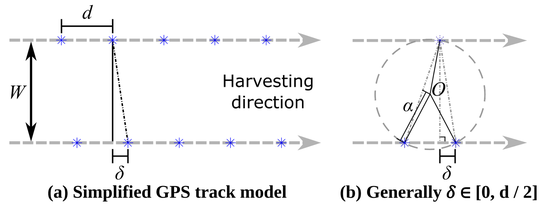
Figure 4. The Output High-Precision Field Shape for One Example Field in the 2014 Dataset

In-field Classification[c]

- Gets rid of GPS points that are not in the field
- Takes advantage of the patterns in combine speed and road shapes

α-shape Generation

- A fast and adjustable algorithm to form the "shape" for a cluster of points
- Purely geometric / It ignores time information
- Fast: with complexity $O(n \log n)$
- A simplified GPS track model for harvesting is constructed for computing α



(a) Simplified GPS track model

(b) Generally $\delta \in [0, d/2]$

(c) Smallest α

(d) Largest α

Figure 5. A Model for Combine GPS Points inside Fields

- The optimum value for α obtained:

$$\alpha = \frac{\sqrt{W^2+\delta^2}\cdot\sqrt{W^2+(d-\delta)^2}}{2W} \quad (1)$$

$$\hat{\alpha} = \alpha_{Max} + 2\sigma \approx (5.38 + 2\times 3)\,\mathrm{m} = 11.38\,\mathrm{m} \quad (2)$$

A fully-automatic and easy-to-implement algorithm[a] to dynamically generate high-precision field shapes via combine GPS tracks[b] during harvesting seasons.

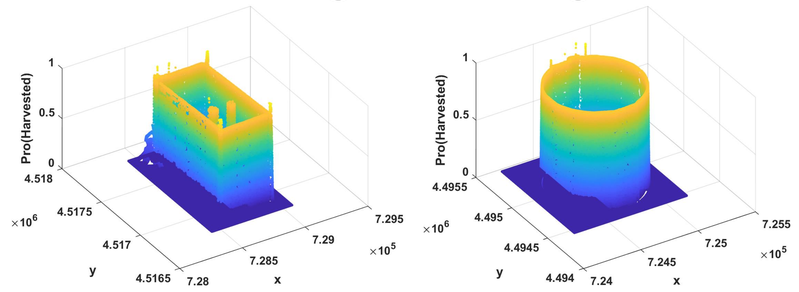


Figure 3. Statistical Harvest on Edges for Two Example Fields

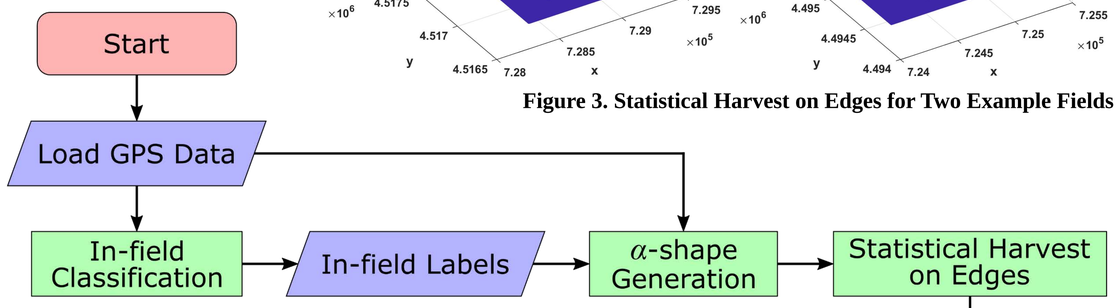
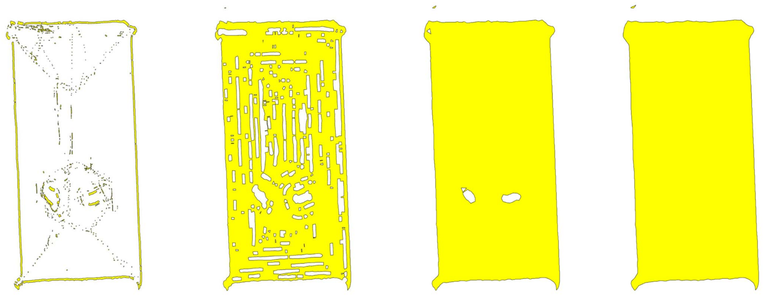


Figure 1. Algorithm Overview



(a) α = 1 (b) α = 5 (c) α = 10 (d) α = 20

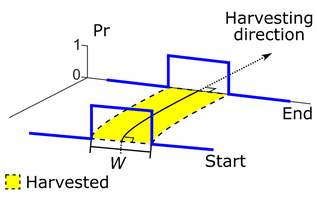
Figure 2. Illustration of α-shape Generation with Different Values for α (m)

Statistical Harvest on Edges

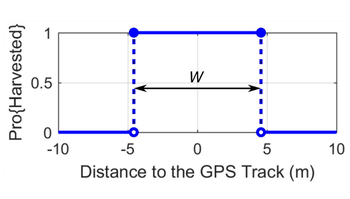
- Takes advantage of the time and accuracy information in GPS samples
- Assigns the probability of being harvested to points in a grid, following the combine GPS tracks
- Considers header width, GPS error and tablet installation offset to form the "statistical header"

$$P_H(x) = \int_{-\infty}^{+\infty} \Pr(L=l)P_{H_0}(x-l)dl = \int_{x-W/2+\Delta}^{x+W/2+\Delta} \Pr(L=l)dl = \Phi\left(\frac{x+W/2+\Delta}{\sigma}\right) - \Phi\left(\frac{x-W/2+\Delta}{\sigma}\right) \quad (3)$$

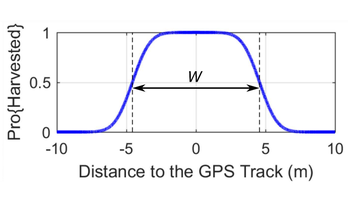
- Properly extends the shapes in our algorithm



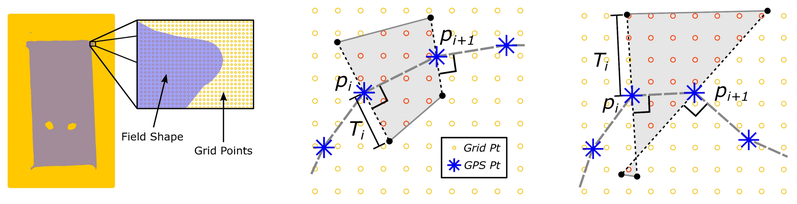
(a) Illustration for a statistical harvest



(b) Gate-shaped assignment

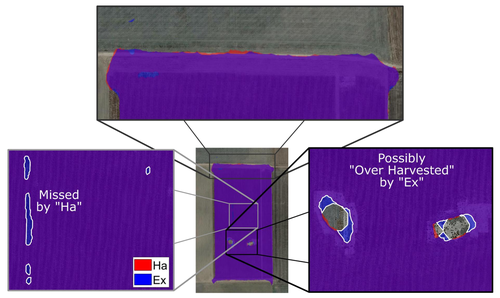


(c) The effect of GPS error

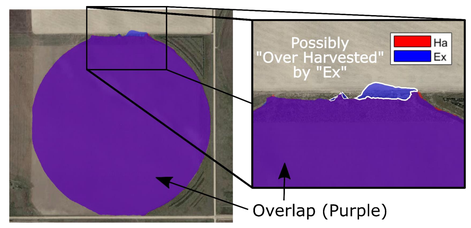


(d) The discrete version implemented in the algorithm

Figure 6. Illustration of the Statistical Replay for Harvesting



(a) A square-shaped field

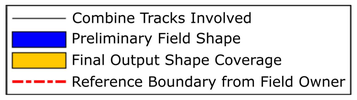


(b) A circle-shaped field

Figure 7. Output Field Shape Comparison for Statistical Harvest Alone (Ha) vs the Field Shape Generation (Ex) Algorithm

Results

- Our algorithm's outputs are compared with corresponding boundaries from the field owner



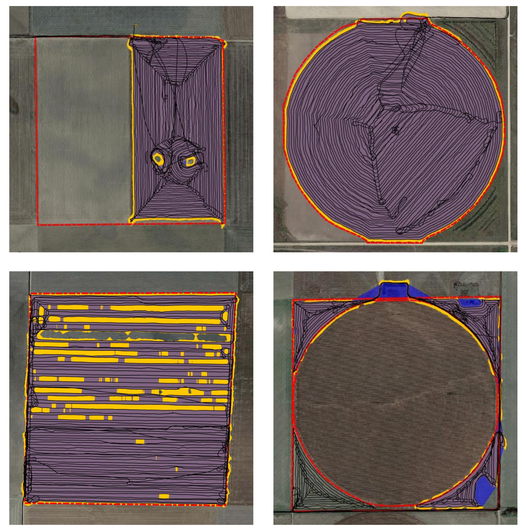


Figure 8. Coverage Comparison for Different Kinds of Field Shapes

Conclusion

- Resulted field shapes agree really well with the boundaries provided by the farmers
- But they also capture way more details about which exact parts have been harvested

Acknowledgement

Thanks to Krogmeier Farms, Amherst, Colorado for assisting with the data collection.

[a] Implemented using Matlab. More about Matlab at: https://www.mathworks.com/products/matlab.html
Matlab code available at: https://github.com/YaguangZhang/GpsDataVisualizationAndAnalysisWorkspace.git

[b] We have collected the GPS data for 2 wheat harvesting seasons using an Android app we developed.
Android code available at: https://github.com/OATS-Group/CombineKartTruck.git

[c] More details in "Zhang, Y., Balmos, A. D., Krogmeier, J. V., & Buckmaster, D. (2015). *Working Zone Identification for Specialized Micro Transportation Systems Using GPS Tracks.* Paper presented at the 2015 IEEE 18th International Conference on Intelligent Transportation Systems".