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Zhang

Biography

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Poster Title: Dynamic High-Precision Field Shape Generation via Combine GPS Tracks

Authors: Yaguang Zhang, Andrew Balmos, James Krogmeier, Dennis Buckmaster

Abstract:

Fields are in practice the most fundamental elements for agricultural management. Crops within the same field are usually not only treated similarly as a group during planting, growing and harvesting, they are also often analyzed together to represent the performance of that particular field. Currently, fields are often defined as areas inside some static field boundaries previously decided by the operator. However, the shape for the actual area in a field which yields valid products may change dramatically over time because of weather, natural terrain changes, in-field constructions and field management decisions. And the current static approach to defining fields makes it hard for comprehensive high-precision performance evaluation. In this paper, we propose to utilize GPS tracks for combine harvesters during the harvesting season to extract up-to-date, high-precision field shapes. We use the notion of α -shape to outline the fields and detect holes inside them. After that, another technique, statistical replay for harvesting, is used to reasonably extend the field shapes. The whole algorithm is fully automatic and the field boundaries generated by it agree with the ones provided by the field owners, but capture far more details, like holes, which are parts not suitable for farming, inside the fields. We also looked at some possible application cases for our algorithm. Results for the same fields in different years are compared, and the differences we see in fact reflect several important decisions made by the farmers.

Dynamic High-Precision Field Shape Generation via Combine GPS Tracks

Yaguang Zhang¹, Andrew Balmos¹, James Krogmeier¹, Dennis Buckmaster²

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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- Field boundaries are currently troublesome to generate and thus usually outdated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

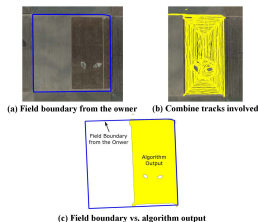


Figure 4. The Output High-Precision Field Shape for One Example Field in the 2014 Dataset

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

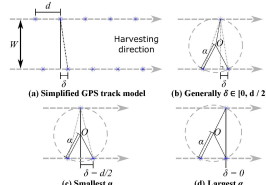


Figure 5. A Model for Combine GPS Points inside Fields

- The optimum value for α obtained:

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

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

^[a] 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".

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

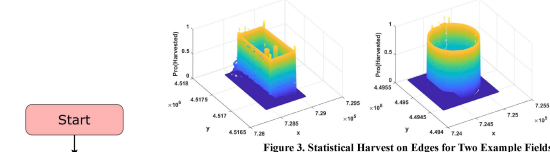


Figure 3. Statistical Harvest on Edges for Two Example Fields

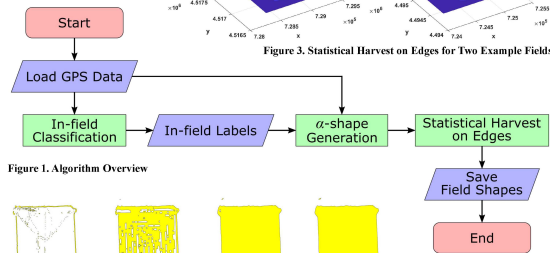


Figure 1. Algorithm Overview

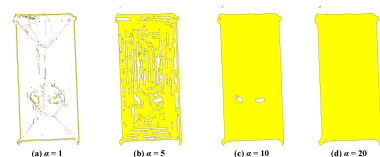


Figure 2. Illustration of α -shape Generation with Different Values for α (m)

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"

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

- Properly extends the shapes in our algorithm

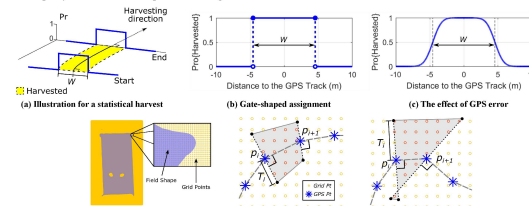


Figure 6. Illustration of the Statistical Replay for Harvesting

^[b] Implemented using Matlab. More about Matlab at: <https://www.mathworks.com/products/matlab.html>
 Matlab code available at: <https://github.com/YaguangZhang/CombineGPSDataVisualizationAndAnalysis/blob/master/>
^[c] 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/CombineFarmTrack.git>

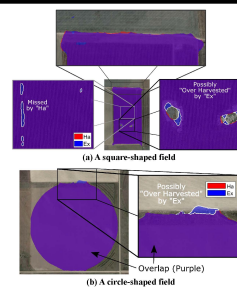


Figure 7. Output Field Shape Comparison for Statistical Harvest Alone (Ha) vs the Field Shape Generation (Ex) Algorithm

Results

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

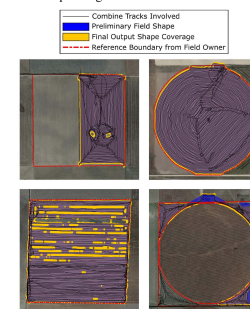


Figure 8. Coverage Comparison for Different Kinds of Field Shapes

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.



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Poster Title: Generating Product Traceability Trees for Harvesting from GPS Tracks

Authors: Yaguang Zhang, Andrew Balmos, Aaron Ault, Dennis Buckmaster, James Krogmeier

Abstract: With increasing concerns about food safety worldwide in many countries, product traceability has become an irreplaceable risk-management tool. It enables the identification of possible sources for defective goods, and furthermore, the withdraw or recall of affected products to protect consumers from foodborne diseases. However, it is troublesome for farmers to maintain records required by high-precision product traceability during harvesting, because traditional traceability systems usually involve human labor in paper work or extra expenses on electronic equipment purchase and installation, and either way the resulting records are normally far away from user-friendly. In this work, a fully-automatic algorithm is proposed for efficiently generating product traceability trees to visualize and store the full transportation record of wheat from fields to elevators. Extending previous works of harvesting activity recognition via GPS tracks, this algorithm demonstrates great potential of tracing product using only GPS logs for vehicles involved in the harvesting. From the output trees, product yielded at any point of the field can be tracked all the way to the elevator where it was sold/stored, by starting from the corresponding leaf and walking all the way to the root of its tree. Furthermore, each truckload of product unloaded together at any destination elevator can be traced back to areas where the corresponding product was harvested, by following the corresponding tree in the opposite direction. In this way, the traceability records can be not only clearly visualized for farmers but also easily utilized by other algorithms.

Generating Product Traceability Trees for Harvesting from GPS Tracks

Yaguang Zhang, Andrew Balmos, Aaron Ault, Dennis Buckmaster, and James Krogmeier

Motivation

- Product traceability is crucial for risk management
- It is troublesome for farmers to maintain records required by high-precision product traceability during harvesting
- Resulting records are normally far away from user-friendly

Background for Wheat Harvesting

- Multiple vehicles may work cooperatively
- Vehicle types: combine harvesters, grain carts, and trucks

Figure 2. Overview maps for the 2017 GPS dataset

Figure 3. Illustrations for wheat harvesting

Product Traceability Tree Design

- A unified way of organizing harvesting, unloading & loading between vehicles, selling at elevators, storing at barns, and any other transfer event if necessary
- Tree data structure is utilized for its advantages in data storage and visualization
- Transfer event locations are represented by GPS samples, recorded by relevant transfer event nodes
- Our system builds trees in a bottom-up approach

Figure 4. Illustrations for wheat harvesting

An Event-Driven Traceability System

- Transfer events are recognized by our previous work
- The product traceability tree builder is responsible for transferring events into a tree data structure for storage
- The visualization subsystem takes care of plotting the tree and responding to user interactions

Figure 5. Automatically-generated event list

Goals

- A prototype product traceability system for harvesting
- From raw GPS data to high-level insights on logistics
- As automatic as possible

Figure 1. Overview for the prototype traceability system

Transfer Source Layers

Root: Done

- Elevators
- Trucks
- Combine Harvester
- Grain Cart

Figure 6. Designing a product traceability tree for visualizing all transfer events

Transfer Event Tree for Traceability

Figure 7. The interactive visualization system

Discussion

- The prototype system is low-cost and easy-to-implement
- Accuracy has been traded for high-level automation
- Traceability could be improved with more automatically-generated data, e.g. CAN bus messages

Figure 8. Tracing product down the tree

Conclusion

- A fully-automatic algorithm is proposed to efficiently build product traceability trees for wheat harvesting
- A prototype traceability system has been implemented to illustrate the potential of these product traceability trees

Acknowledgements

Thanks to Krogmeier Farms, Amherst, Colorado, for assisting with the data collection.
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Poster Title: Large-Scale Cellular Coverage Analyses for UAV Data Relay via Channel Modeling

Authors: Yaguang Zhang, Tomohiro Arakawa, James V. Krogmeier, Christopher R. Anderson, David J. Love, and Dennis R. Buckmaster

Abstract: With the rapid popularity of unmanned aerial vehicles (UAVs, also known as drones), UAV data relay has demonstrated potential extending wireless communication coverage, especially for rural areas. The flexibility of this approach has attracted research attention from a variety of areas, including Internet of Things, intelligent transportation systems, and digital agriculture. However, most current research effort focuses on modeling and theoretically optimizing data relay systems via UAV trajectories in simplified geographic environments, while taking advantage of UAVs for practical wireless communication networks requires large-scale quantitative performance analysis results based on real-life environment information. In this work, we propose algorithms for generating large-scale blockage and path loss maps via terrain-based channel modeling for cellular communication systems with fixed-height relay drones. Our analyses reveal the coverage ratios for Tippecanoe County and the Wabash Heartland Innovation Network region in Indiana, with relay drones simulated at different heights. A coverage ratio gain over 40% can be achieved at a drone height of 100 m, compared to a typical pedestrian height of 1.5 m. These site-specific analyses are important in locating poorly covered spots and quantifying the coverage improvement from UAV data relay.

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