Generating Product Traceability Trees for Harvesting from GPS Tracks

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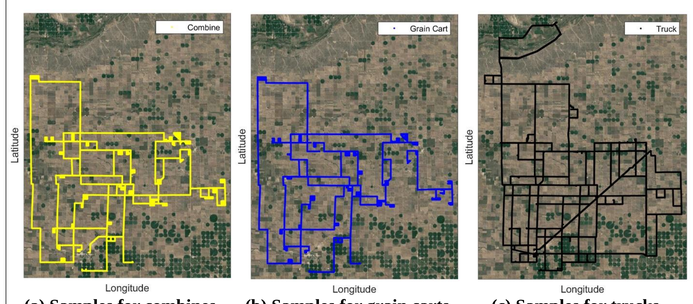
Motivation

- 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



(a) Samples for combines (b) Samples for grain carts (c) Samples for trucks

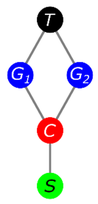
Figure 2. Overview maps for the 2017 GPS dataset

(a) Overview (b) Vehicle indices (c) Unloading (24 to 58)

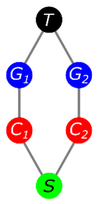
Figure 3. Illustrations for wheat harvesting

Product Traceability Tree Design

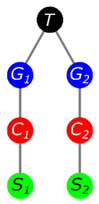
- A unified way of organizing harvesting, unloading & loading between vehicles, selling at elevators, storing at barns, and any other transfer event if necessary
- Tree data structure is utilized for its advantages in data storage and visualization
- Transfer event locations are represented by GPS samples,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



(a) Intuitive arrangement



(b) Splitting *C*



(c) Splitting *S*

Figure 4. Illustrations for wheat harvesting

An Event-Driven Traceability System

- Transfer events are recognized by our previous work[c]
- 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

vehId	type	event	idFrom	idTo	estiTimeStart	estiTimeEnd	vehFileIdx	fileIdxFrom	fileIdxTo	estiGpsTimeStart	estiGpsTimeEnd
...	...	...	...	...	...	...	...	...	...	...	...
p e 7130	Combine	u2k	p e 7130	p and e 290	7/1/2017 13:12	7/1/2017 13:13	239	239	233	1.49893E+12	1.49893E+12
p and e 6130	Combine	u2k	p and e 6130	p and e 290	7/1/2017 13:17	7/1/2017 13:18	243	243	233	1.49893E+12	1.49893E+12
p e 7130	Combine	u2k	p e 7130	p and e 290	7/1/2017 13:21	7/1/2017 13:23	239	239	233	1.49893E+12	1.49893E+12
p and e 290	Grain Kart	u2t	p and e 290	p and e red peterb	7/1/2017 13:24	7/1/2017 13:29	233	233	203	1.49893E+12	1.49893E+12
p and e 6130	Combine	h	Fields	p and e 6130	7/1/2017 13:28	7/1/2017 13:28	243	0	243	1.49893E+12	1.49893E+12
p and e 6130	Combine	h	Fields	p and e 6130	7/1/2017 13:28	7/1/2017 13:29	243	0	243	1.49893E+12	1.49893E+12
p and e 6130	Combine	h	Fields	p and e 6130	7/1/2017 13:29	7/1/2017 13:29	243	0	243	1.49893E+12	1.49893E+12
p and e 6130	Combine	h	Fields	p and e 6130	7/1/2017 13:29	7/1/2017 13:29	243	0	243	1.49893E+12	1.49893E+12
p e 7130	Combine	h	Fields	p e 7130	7/1/2017 13:29	7/1/2017 14:28	239	0	239	1.49893E+12	1.49893E+12
p and e 6130	Combine	h	Fields	p and e 6130	7/1/2017 13:29	7/1/2017 13:54	243	0	243	1.49893E+12	1.49893E+12
p and e 6130	Combine	u2k	p and e 6130	p and e 290	7/1/2017 13:32	7/1/2017 13:33	243	243	233	1.49893E+12	1.49893E+12
p e 7130	Combine	u2k	p e 7130	p and e 290	7/1/2017 13:39	7/1/2017 13:41	239	239	233	1.49893E+12	1.49893E+12
p and e red peterb	Truck	u2e	p and e red peterb	Elevator Grainland Cooperative in Amherst	7/1/2017 13:43	7/1/2017 13:55	203	203	inf	1.49893E+12	1.49893E+12
p and e 6130	Combine	u2k	p and e 6130	p and e 290	7/1/2017 13:48	7/1/2017 13:50	243	243	233	1.49893E+12	1.49893E+12
p and e 6130	Combine	h	Fields	p and e 6130	7/1/2017 13:54	7/1/2017 14:37	243	0	243	1.49893E+12	1.49893E+12
p e 7130	Combine	u2k	p e 7130	p and e 290	7/1/2017 13:55	7/1/2017 13:57	239	239	233	1.49893E+12	1.49893E+12
...	...	...	...	...	...	...	...	...	...	...	...

Figure 5. Automatically-generated event list

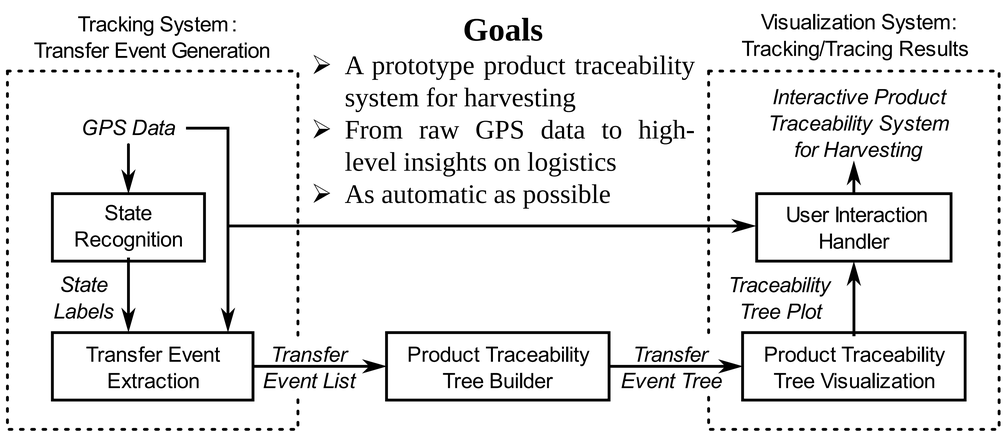


Figure 1. Overview for the prototype traceability system

Goals

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

A fully-automatic algorithm[a] to build product traceability trees for harvesting via GPS tracks[b].

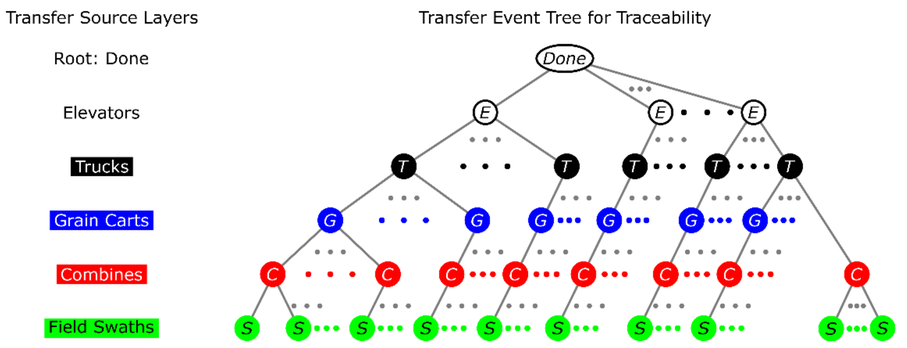
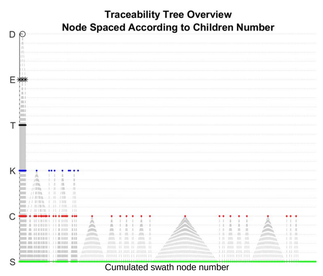
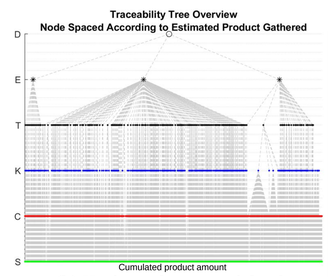


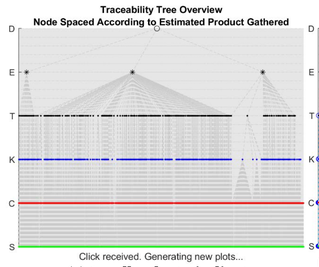
Figure 6. Designing a product traceability tree for visualizing all transfer events



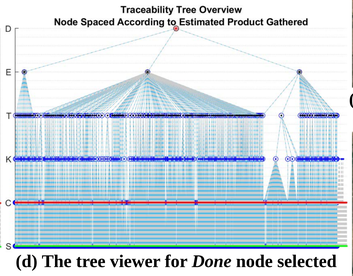
(a) Horizontal space weighted by children amount



(b) Horizontal space weighted by estimated product amount



(c) Feedbacks to indicate user input blockage

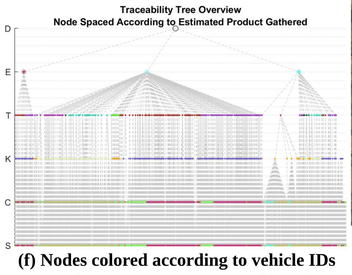


(d) The tree viewer for *Done* node selected

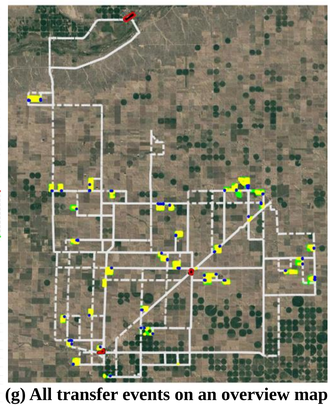
```
InterTraceTree: Click received.
InterTraceTree: Generating meta data for the
                initial click...
InterTraceTree: The node below has been selected.
                   nodeId: 'Done'
                   parent: NaN
                 children: {1×3 cell}
                  fileIdx: NaN
estiGpsTimeStartUnloading: NaN
  estiGpsTimeEndUnloading: NaN

InterTraceTree: Tracing up and down the tree ...
InterTraceTree: Generating map view...
                Fetching GPS tracks...
InterTraceTree: Fetching data for truck tracks ...
                Plotting...
InterTraceTree: Done!
```

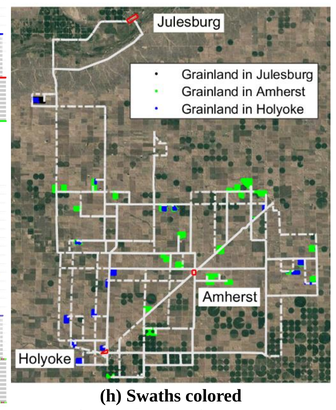
(e) Message feedbacks in the console



(f) Nodes colored according to vehicle IDs



(g) All transfer events on an overview map



(h) Swaths colored by destination elevators

Figure 7. The interactive visualization system

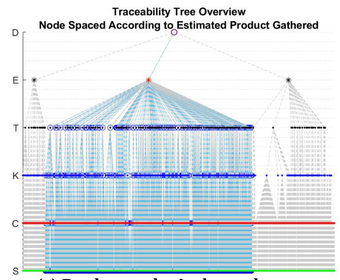
[a] Implemented using Matlab. More about Matlab at: https://www.mathworks.com/products/matlab.html
Matlab code available at: https://github.com/YaguangZhang/GpsDataVisualizationAndAnalysisWorkspace.git

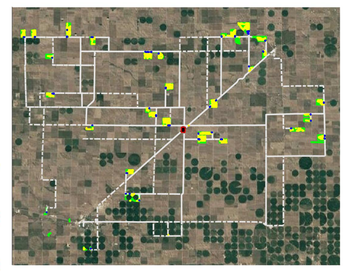
[b] We have been collecting GPS data during wheat harvesting seasons using an Android app we developed. Android code available at: https://github.com/OATS-Group/CombineKartTruck.git

[c] More details in "Zhang, Y., Ault, A., Krogmeier, J. V., & Buckmaster, D. (2017). *Activity Recognition for Harvesting via GPS Tracks*. In 2017 ASABE Annual International Meeting (p. 1). American Society of Agricultural and Biological Engineers".

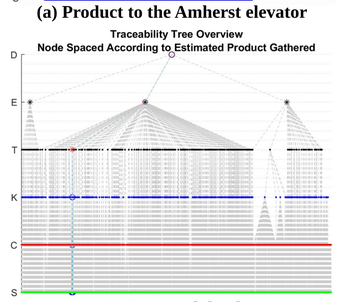
Discussion

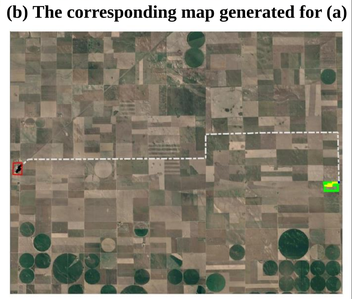
- The prototype system is low-cost and easy-to-implement
- Accuracy has been traded for high-level automation
- Traceability could be improved with more automatically-generated data, e.g. CAN bus messages



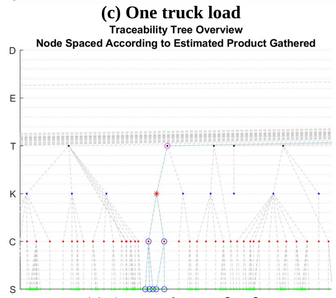


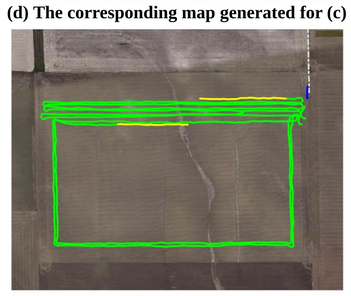
(a) Product to the Amherst elevator (b) The corresponding map generated for (a)



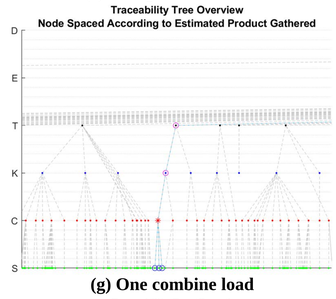


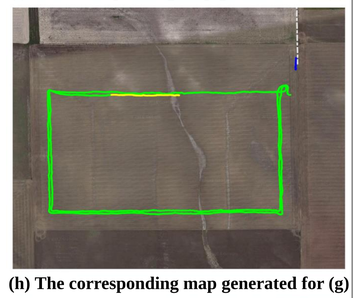
(c) One truck load (d) The corresponding map generated for (c)



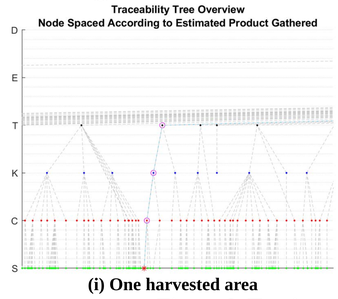


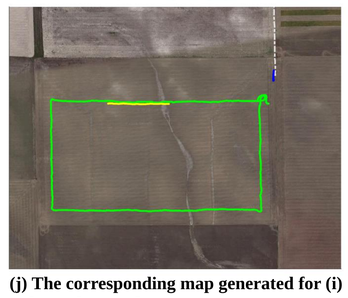
(e) One grain cart load (f) The corresponding map generated for (e)





(g) One combine load (h) The corresponding map generated for (g)





(i) One harvested area (j) The corresponding map generated for (i)

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.
Thanks to Foundation for Food and Agriculture Research and CNH Industrial, for supporting the OATS Center.