Using Engineering Tools to Streamline the Forage Harvest Process

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A Need For Efficiency

- United States corn production for silage reached 128 million tons in 2014.
- Large input of time and energy is necessary to produce silage.
- Producers often employ multiple self-propelled forage harvesters (SPFH) and many transport vehicles for harvest.
- Proper management of this fleet is a logistical challenge, with significant opportunities for efficiency improvements.

Analysis of Forage Harvest

Alfalfa harvest in Sun Prairie, Wisconsin, 2015.

- **A study was conducted to observe forage harvest and determine in-field efficiency.**
- In-field efficiency of forage harvest is affected by machinery movement and actions.
- Observation of forage harvest process can be used to identify opportunities to increase efficiency:
  - Idle harvesters
  - Idle transport vehicles
  - Too many/ too few transport vehicles

Time-Motion Study

- Research was conducted at a commercial dairy in Sun Prairie, WI.
- The producers employ:
  - 2 SPFH
  - 10 straight trucks
  - 2 tractor-trailers
- During the 2015 growing season:
  - 450 ac rye
  - 1600 ac alfalfa
  - 2000 ac corn

Chopping alfalfa into a tractor-trailer.

Unloading at a bunker.

Data Recording Methods

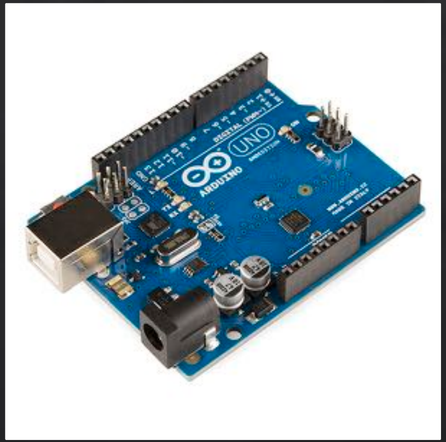
CANcaseXL installed behind monitor in harvester.

Arduino loggers installed in cabs of trucks.

- Machine movement was tracked during harvest via Global Positioning System (GPS) receivers:
  - Arduino Uno loggers
  - Vector CANcaseXL loggers
- Non-CAN equipped vehicles (trucks, semis) used Arduino loggers.
- CAN equipped vehicles (SPFH, tractors) used Vector loggers.
- GPS tracking allowed vehicles paths to be recorded.
- CAN data allowed vehicle work status to be determined.

Arduino Uno GPS loggers

- Components:
  - Arduino Uno
  - EM-506 GPS receiver
  - GPS shield
  - Micro-SD shield
- Installed in the cab of each truck and powered by the vehicle battery.
- Stored GPS data on SD card at 1 Hz.
- GPS data includes important information:
  - Position
  - Heading
  - Speed



- Arduino Uno: open-source microcontroller used as a processor to capture and store GPS data from receiver onto micro-SD card.

Vector CANcaseXL

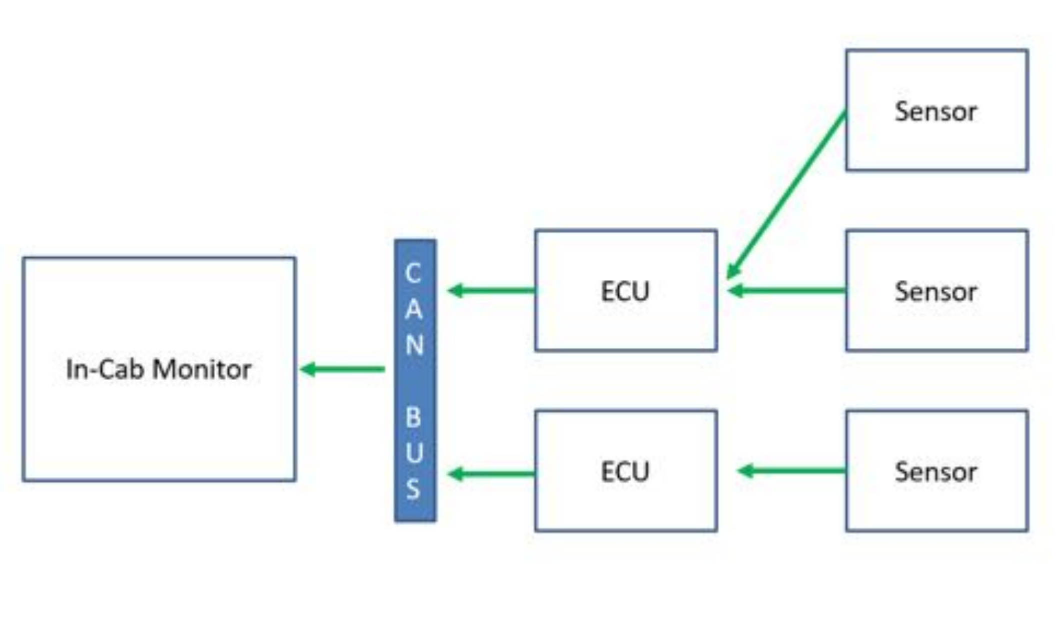
- Professional data logging platform capable of storing Controller Area Network (CAN) data and GPS data simultaneously.
- CAN signals from harvesters (vehicle speed, cutterhead speed) stored alongside GPS position in one binary log file.
- CAN data is recorded at extremely high frequency.
- GPS data recorded at 1 Hz.

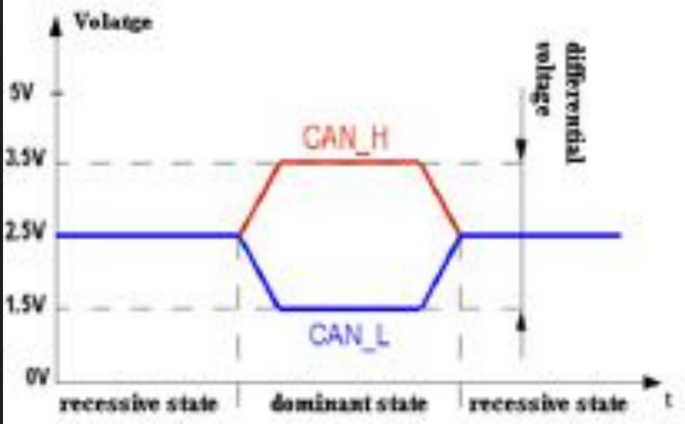
Controller Area Network (CAN) signals

- Sensors and control devices on equipment allow operator to monitor virtually all aspects that affect performance.

- The way these components communicate are via messages passed through the CAN bus.

- Standards allow manufacturers to produce machines that all speak the same "language."



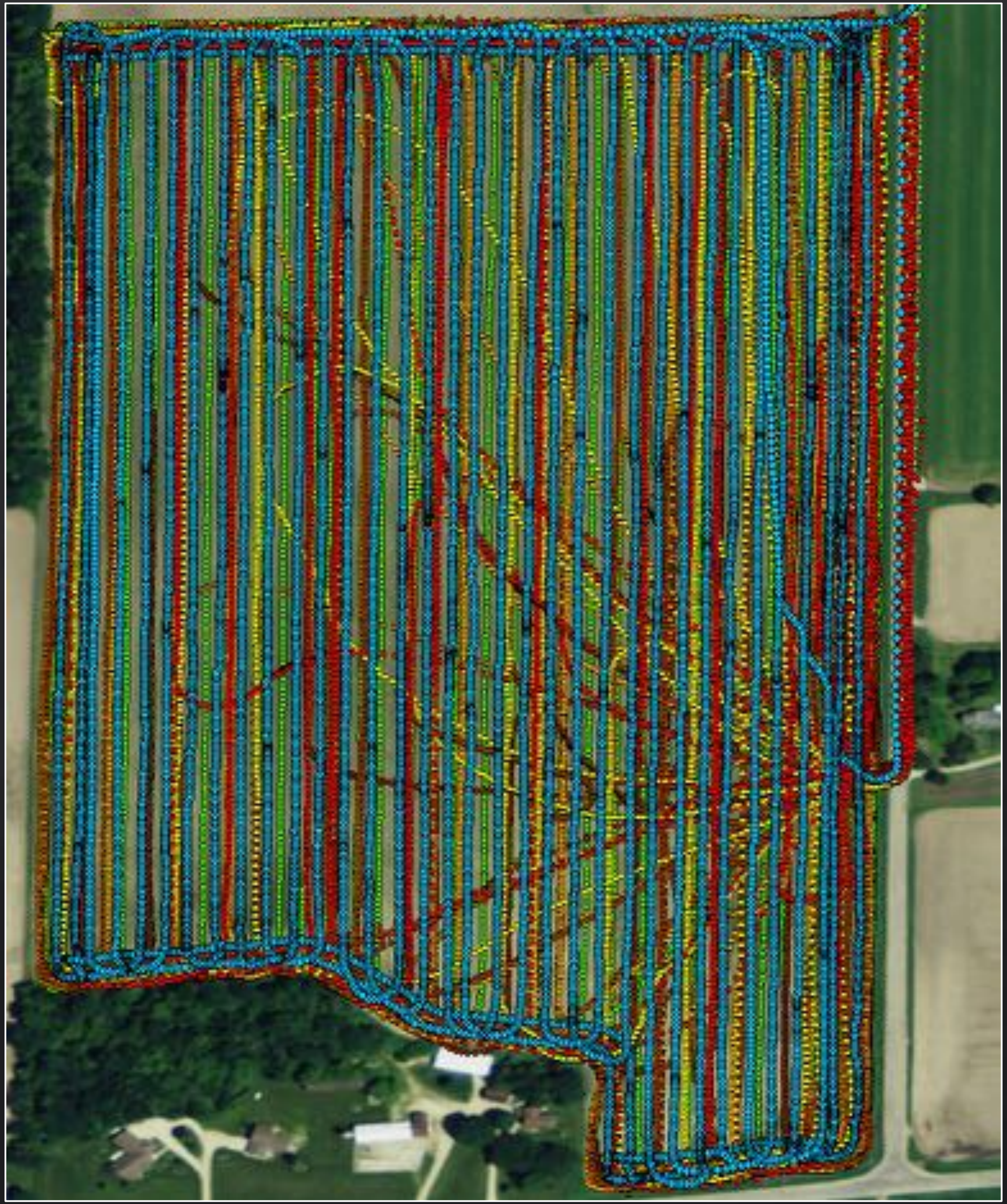


Research Objectives

- GPS and CAN data from vehicles will be used to develop linear models that fit each harvest.
- These models are defined by:
  - Number of vehicles used in harvest
  - Vehicle work status
  - Action times (time to fill, time to unload, etc.)
- Models identify practices that reduced harvest efficiency.
- Manipulate models in order to determine number of trucks needed, based on:
  - Reduce harvester idle time
  - Reduce truck idle time
- These models are developed for each field harvested.
- Can be used to relate transport distance to number of trucks needed.

2015 Ryelage Harvest

- Harvester pictured in blue
- 6 trucks
- 1 merger



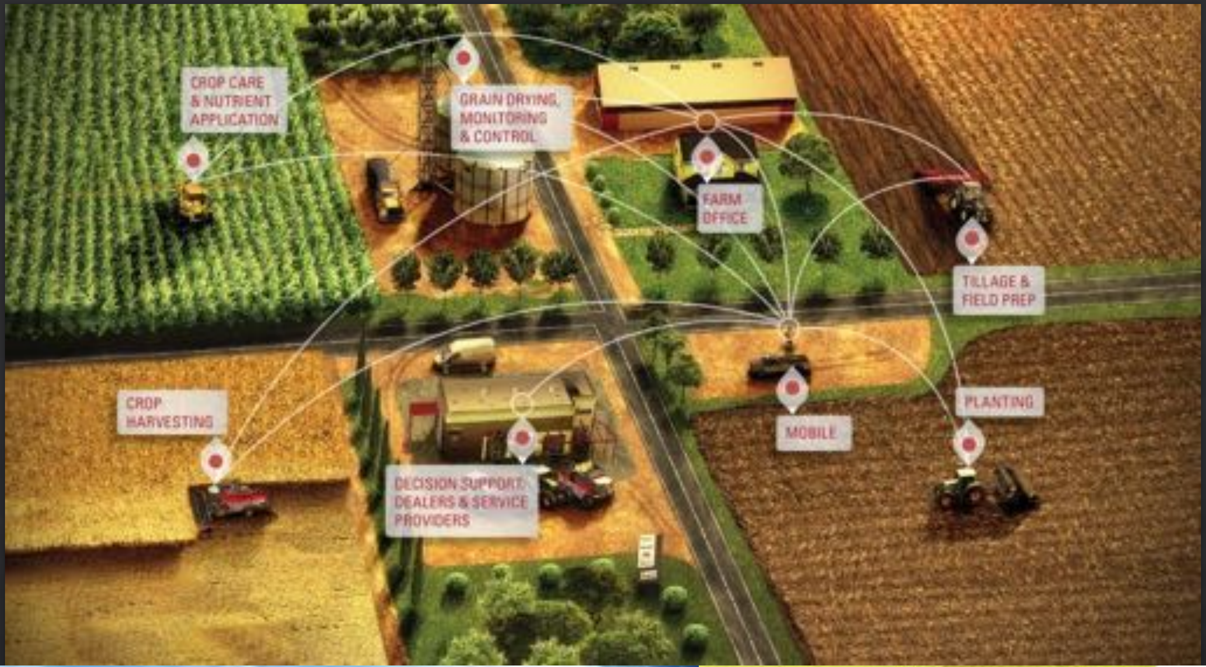
Model Details

- $I = W - N * F$, where:
  - I is idle time.
  - W is truck work time.
  - N is number of trucks.
  - F is fill time.
- Truck work time, W, is defined as:
  - Drive to bunker, T_b.
  - Unload, T_u.
  - Drive to field, T_f.
- $W = F + T_b + T_u + T_f$

- Example to determine chopper idle time:
  - $F = 2.8 \text{ minutes}$
  - $T_b = 7 \text{ minutes}$
  - $T_u = 1.4 \text{ minutes}$
  - $T_f = 6 \text{ minutes}$
  - $N = 6 \text{ trucks}$
- Solve for truck work time, W:
  - $W = 2.8 + 7 + 1.4 + 6 = 17.2 \text{ minutes}$
- Insert truck work time into model:
  - $I = 17.2 - 6 * 2.8 = 0.4 \text{ minutes}$
- The harvester is idle for 0.4 minutes between trucks.

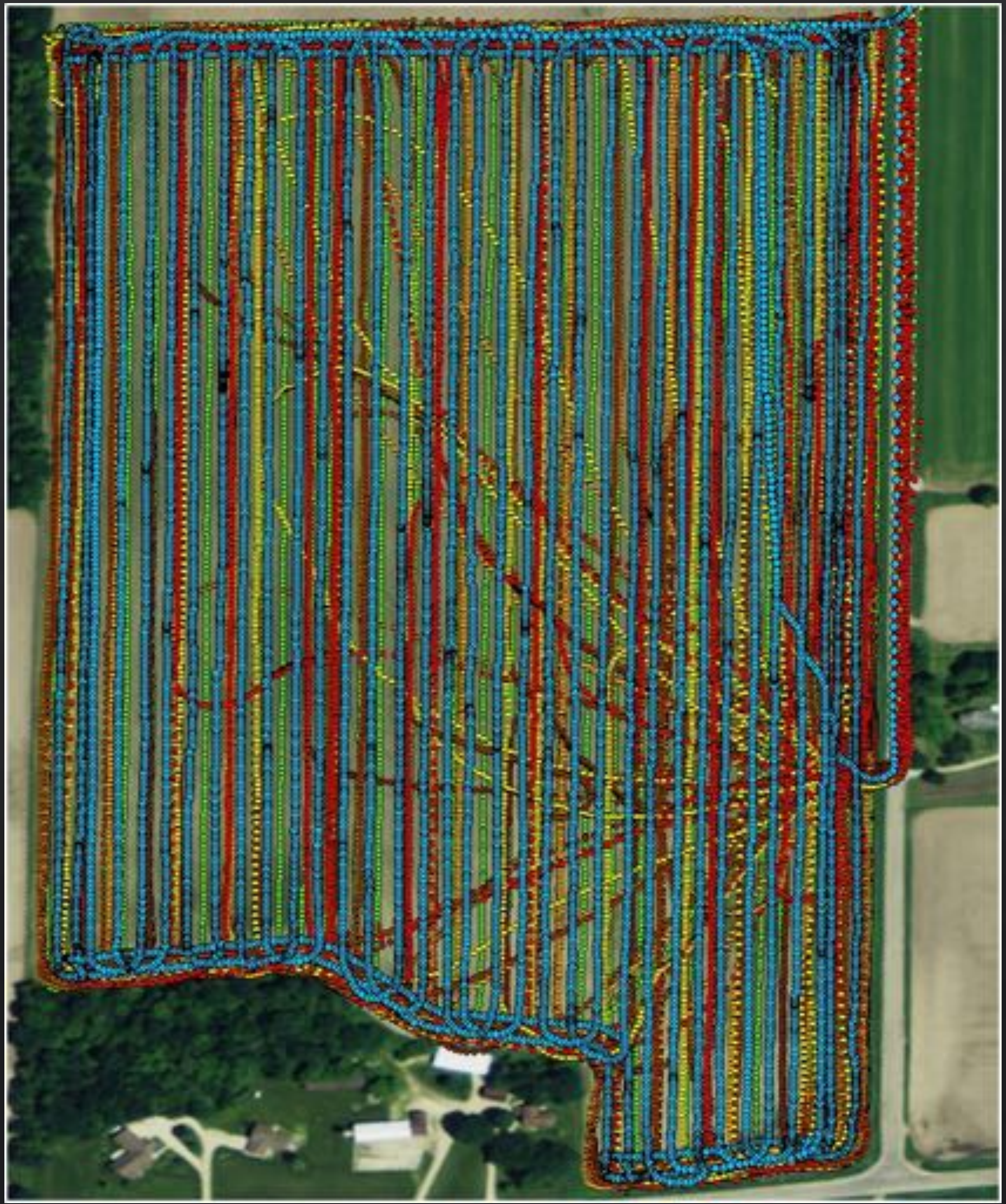
Future Work

- Define "rules" for identifying machine status from GPS and CAN data
- Finalize linear model for optimal resource allocation
- Adjust operating parameters for cooperating farm to assess efficiency gains early season 2016
- Develop telematics system for machine management during forage harvest



Telematics Operation

- Define “Master” machines
  - Forage Harvester (obvious)
  - Packing Tractor (secondary master)
- Identify location of bunker and field inlets
- Each transport vehicle has a communication link to Master machines (two-way)
- Field exit and return route defined by location of Master, state of Master, state of Secondary Master, and other parameters
- Real-time process optimization
- Correction for unforeseen circumstances
  - Machine break-down
- Light Bar Guidance for transport vehicles
  - Control traffic to manage soil compaction



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