Potato Yield Mapping Methods
by
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Introduction/Product History
HarvestMaster, Inc. is a Logan, Utah based agricultural electronics company dedicated to providing Information Machines for Agriculture. Over the past few years, we have focused primarily on field data collection systems for AG researchers doing variety testing and plant breeding.

During the fall of 1993 we were solicited by a potato farmer in South East Idaho to provide data logging capabilities for their yield mapping program. We provided the data loggers, and Washington State University provided a research physicist to instrument the harvester, program the data logger and acquire the data. To our knowledge this was the first continuous flow yield maps done for potatoes.

About the same time, Dr. Steve Rawlins of USDA-IAREC in Prosser, WA invited us to cooperate with him in the mapping of corn, wheat and potatoes at their research sit in Patterson, WA. In 1994, potato yield was again mapped at the USDA site as well as portion of a center pivot in the Columbia River Basin of Washington. After the 1994 season, some product improvements and revisions were made, and a beta test release was scheduled for the fall of 1995. Seven units were sold on a beta-test basis to companies and growers in Washington, Idaho, Minnesota and North Dakota. Potato yield was mapped on between 500 and 1000 acres of potatoes and sugar beets. This included five complete center pivots in Washington.

Objectives
At the beginning of this project, we identified three key reasons for developing this technology. They are;

1) It makes a lot of sense to move AG research farm activity to the actual farm where those results will be expected to be valid. This is, we had ought to be doing our research on the same soils, with the same tillage practices, and in the same climate as where we plan to use the results.
2) There appear to be many gains possible in terms of site specific management practices on the farm. Site specific yield information is one of the critical pieces of information required before implementing site specific farming.
3) There has been a lot of work done in the mapping of yields from grains - corn, wheat, and soybeans; but none, to our knowledge on the yield mapping of bulk crops such as potatoes and sugar beets. Our overall objective was to determine if such a system were feasible.
Next, we determined the key objectives that needed to be met in the field for producers to adopt this technology. These are:

1) Develop a simple conveyor weighing method.
2) Integrate the weighing sensors with a suitable data acquisition system.
3) Incorporate an accurate harvester position sensor with the yield sensor.
4) Develop a method to transform raw field measurement into yield maps.
5) Design the system to be both durable and easy to operate.

System Design
The overall operation of the system consists of four modules working in unison. These are, weight measurement, position measurement, signal conditioning and control, and serial communications and data storage.

Weight Measurement
The weight measurement system consists of a pair of load cells and a conveyor speed sensor. The load cells are designed to replace a set of idler wheels opposite of each other on the final delivery conveyor of the harvester. Load cell placement is the most critical aspect of a successful installation. Improper placement can lead to inaccurate weight readings, and worse, loss of data and diminished return on investment. The load cells should be placed in a flat section of conveyor that will not be affected by raising and lowering of the boom. The roller on the load cell should be no higher or lower than the upstream and downstream idler rollers. The conveyor speed sensor should be mounted so that it is facing the shaft of the conveyor drive system. A magnet is attached to the shaft, and the speed sensor is placed so their is approximately 1/4" between the tip of the sensor and the magnet. Weight per unit length of the conveyor multiplied by conveyor travel per second gives weight of product per second, a mass flow measurement.

Position Measurement System
For position measurement we used the Global Positioning System (GPS), operated by the Department of Defense. GPS is a constellation of 24 satellites in continuous orbit around the earth. Orbiting satellites are continuously sending out a signal. Receivers here on earth pick up the signal and determine where the receiver is approximately located. For agricultural purposes, we must use Differential GPS in order to have high enough accuracies for yield mapping and other site specific applications. DGPS requires a base station to be positioned over a known locations on the earth. The base station receives the GPS signal, calculates the difference between where the GPS says it is and where the base station knows it is located. The base then sends out a correction factor to the roving receiver. Simultaneously, the receiver on your harvester is picking up the raw GPS signal and also the correction factor from the base. With this information, the roving unit calculates where it is at that moment in time. This process can be repeated every second. Typical DGPS accuracies range from less than 20 inches to 15 feet depending on the quality of the GPS equipment you are using.
For our tests this year, we used GPS equipment from Ashtech and Trimble Navigation. Both systems performed very well in the field. The Ashtech system was rated as sub-meter and performed typically in the 70 - 80 cm range. The Trimble receiver was rated at 2-5 meters and performed well within the specifications outlined. For the 1996 season we will be supporting our system to work in conjunction with Ashtech, Trimble, NovAtel and Rockwell GPS receivers.

Along with the on harvester GPS receiver, it is necessary to have a Differential Correction Signal from somewhere. There are three options typically available. 1) A producer can invest in their own base station. The advantage would be to have control and access to the signal at all times. The disadvantage is the cost to purchase and then maintain a DGPS base station. 2) There are several differential correction services available for an annual fee. You can typically purchase the accuracy of signal you want. Higher accuracy signals do cost a little more. 3) Lastly, many areas of the U.S. are covered by the Coast Guard Beacon System. This includes major inland waterways, the Great Lakes area and coastal areas. The signal is free, but you still have to purchase a receiver. Individual producers will have to determine which option best meets their need.

Signal Conditioning and Control Unit (SCCU)

The SCCU functions to convert raw weight and conveyor speed into readable information and to receive position information. When the harvester starts to operate, the load cells output a raw signal, as does the speed sensor. The conditioning portion of the SCCU makes this information understandable to the computer. We are receiving a GPS position at a given interval that is set by the user. Typical intervals are 1, 3, or 5 seconds. Weight is continually being accumulated. At a given time interval a GPS position is requested. Calculations are made based on distance traveled and swath width to determine the area harvested between GPS position. Weight divided by area give as yield in sacks per acre. The yield at that GPS position is sent to, and stored in a file via a serial communications link.

Serial Communications and Data Storage

In order for the Yield Monitor to give us any valuable information, we must have a means of communicating with it, and it must have a means of sending us the information it is measuring. This process is controlled through a serial communications link. A computer is located in the cab of the tractor and a cable is attached between the SCCU and the computer. The computer serves two functions. First, it tells the SCCU what information to collect at what time interval, as well as serving to calibrate and trouble shoot the system. Second it collects and stores the data received from the yield monitor. Data is stored in an ASCII comma delimited file for easy transfer to software mapping packages.

Data Collection Issues

Through the 1995 harvest season, it became evident that growers didn’t want to be transferring data back to the office PC all the time. In fact most growers wanted to be
able to store the data for an entire season on the task computer and then retrieve the data at the end of harvest. There are some options that are available to accomplish this. Data was stored in a standard ASCII file. This type of file is easily read by any computer, but is not very efficient as far as space required to store the data. 1) One option would be to store data in a Binary file. This would more than double the amount of space available for data storage. It would require the user to have software that would convert the binary data back into ASCII so the office PC could understand it. This software would be available through HarvestMaster. 2) A second option is to use larger memory cards. Cards are available up to 20 Megs now, the only limitation is the cost. 3) A third option would be to use data telemetry. This means that as data is collected on the harvester it is sent via a radio link back to the office PC. Once the data is safe on the office PC, ten data on the task computer could be deleted or overwritten. This would decrease the need for large capacity data storage on the task computer. All of these options can be made available.

**Yield Map Generation. What do we do with the data?**

Now that we have our data, what do we do with it. Our primary reason for collecting the data was to map crop variability. Many software packages are available that will generate yield maps. After we evaluated several packages, we decided to offer ArcView by ESRI (Environmental Systems Research Institute) to our customers. (See attached yield maps of five center pivots.)

**System Performance**

**Weight Measurement Accuracy**

Accuracy specifications of the system are not officially released yet, but preliminary indications are that 2% is certainly achievable and possibly even 1%. On down side we did see some deviations as high as 10%. Adjustments in load cell placement and some software modifications should put all measurements in the 2% range. North Dakota State University did some of the most extensive accuracy verifications, and they expect there research to indicate accuracies in the 2-3% range.

**Position Measurement Accuracy**

With the equipment we were using, we attained accuracies between sub-meter and 3 meters (roughly, less than 3 feet up to 9 feet). Position accuracy is dependant on the amount of money you have to spend on GPS equipment. Some GPS receiver manufacturers are stating accuracies between 8" and 15".

**1995 Harvest Season Accomplishments**

We felt that a number of our objectives were accomplished this year. The system did prove itself in the field. There were no hardware failures on weight measurement equipment. We did have a minor problem with a GPS receiver, but steps have been taken to correct the problem. System components were integrated into one enclosure, we were
able to use a single task computer to record both yield and position data. Larger acreages were mapped, with even more acres expected in 1996. Perhaps the most important accomplishment was learning what our customers expected from the system.

Enhancements expected for 1996

Some changes will be made to the system for the 1996 North American harvest season. These are;

1) Further reduce package size
2) Improve the quality of the electrical connectors
3) Add Status indicators (for ease in determining if equipment is functioning properly)
4) Set correction for antenna offset (Since the antenna can’t always be in the center of the harvester over the blade, there needs to be a correction factor.)
5) Correct RF interference problem. (CB Radios did cause some interference of the weight measurement. Cables will be protected from RF.)
6) We will offer a variety of task computers for use with the Yield Monitor. These are;
   a) HarvestMaster Pro 2000 Hand-Held Field Computer
   b) HarvestMaster RDT (Rugged Data Terminal) In vehicle computer
   c) Ashtech AG Navigator
   d) Trimble AgGPS (To be announced)
   e) Rockwell Vision System

Conclusions

Much was accomplished during the 1995 harvest season. While our objectives were met, there continue to be improvements and refinements needed. We had anticipated a final product release for the 1996 harvest season, but have decided to do an additional year of product assurance before final release. We will make 30 - 40 units available for purchase this year. We will continue to work closely with growers who make an investment in our product. Any product improvements made after the 1996 season will be upgraded on systems in the field at no additional cost and the warranty will be extended another year. For any additional questions, contact HarvestMaster at your convenience.
1995 Richland Potato - GPS/Yield

- CIRCLE B 88% AVE
- CIRCLE E 99% AVE
- CIRCLE D 113% AVE
- CIRCLE C 106% AVE
- CIRCLE A 95% AVE

Yields are normalized to the average of all five circles.

USDA-ARS & WSU-IAREC
Prosser, Washington

0 0.5 1 Mile