PROJECT TITLE: Develop a field grid system for yield mapping and machine control

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PROJECT AIM: To further develop Field Grid Sense and to demonstrate its suitability for field production applications.

TECHNICAL OBJECTIVES: Build and test the Field Grid Sense system for yield mapping and machine control during harvesting. Secondly, use Field Grid Sense with chemical application equipment to demonstrate a workable in-field system.

More specifically, the operation of the patented hardware/software Field Grid Sense (FGS) system will be tested in crop harvesting to demonstrate the system's utility and to analyze the flexibility of operation under true field conditions. Additionally, FGS will again be used with chemical application equipment - equipment that needs modification to correct one or two slight shortcomings. This action will create improved systems and establish the worthiness, efficiency and necessity of chemical application equipment that is controlled and directed via the FGS package.

Inclusions:
- Final Task Statements
- Final Outcome Summary
- Final Field Prints
- Summarized Quarterly Reports

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Task 1: Expand the preliminary design:

Originally FGS was used with granular chemical application equipment. A primary utility of FGS is its use with each and every phase of crop production cycles. FGS will be adapted to the harvesting phase which will require buying and then modifying crop-harvesting equipment; assembling moisture content, volume and distance sensors on a combine; and arranging the FGS package in situ on the harvesting implement.

1. Buy David Manufacturing Incorporated moisture content sensors, Lucas inclinometers, Magnavox radar distance detectors, Hall-effect sensors with fifth wheel assembly, etc. and interface components and assemble the benchtop arrangement.
2. Bench test the system and analyze the correctness of the design specifications.

Steps of Progress for Task 1:

1s1. Mr. Rod Fischer was hired as a research associate/research assistant. Mr. Stan Nielsen was hired as a research assistant and is also assisting in the areas of software and hardware system development. Rod is perfecting the sprayer manifold and employing FGS with data analysis. Stan employed Kriekging software for data smoothing and analysis plus providing a more useable operation package.

1s2. An electronic harness has been assembled. This is a remake of a previous setup plus we've added workable and available components from our departmental R & D shops. Specific sensors have been selected. Overall electronic configuration have been developed and assembled.

1s3. The combine has been specified; specifications were written and the request was forwarded in the state bid process. The combine was purchased as of 3/15/93.

1s4. Several field tests were previously performed, as described under steps 2s1, 2s2 and 2s3. Also, the software and hardware plus overall system capabilities of FGS are continuously being improved. The field tests done on borrowed equipment plus our joined efforts with Agriculture Information Technologies of Iroquois, SD have been of great benefits. The improved FGS components will continue to be bench tested and used on the purchased combine to effectively and efficiently perform field tests.

1s5. The total combine-FGS assembly is developed, and has been placed on the combine.

1s6. This task is complete.
**Task 2:** Use FGS on the harvesting unit under field conditions

1. Prepare the field harvester with the FGS readout and sensory attachments.
2. Make field runs in University plots, on ARS farms and in producers' fields and observe the system workability; demonstrate system feasibility. Data will be collected from automated field measurements. Collected yield data will include bushels per acre, grain moisture content, grain temperature, field slope measurements, field position, field entered. The collected information will be shown graphically in a software derived fieldmap.
3. Refine the setup and make any necessary adjustments.

**STEPS OF PROGRESS FOR TASK 2:**

2s1. Great progress has been made toward this task. A combine has been purchased (we've spent considerable time and have purchased the needed one); plus, we were fortunate enough to be able to use a Plant Science harvester. The electronic components with computer and FGS were placed on the machines. Further system development took place; we've added program commands.

2s2. A working arrangement was put in place that allowed us to test the FGS/harvester system. Two sites were used at the USDA/ARS farm which is located directly north of Brookings, SD.

2s3. The results of both wheat harvest and corn harvest using the system were reported - it was determined that the system offers advantages over today's farming techniques. Maps and databases of yield, grain moisture and topography were produced which could be utilized in site specific crop management toward savings of inputs. These results were presented at two separate meetings (papers filed with previous report) -
   a) the SAE International Off-Highway & Powerplant Congress & Exposition in Milwaukee, WI
   b) the ASAE Winter Meeting in Nashville, TN

2s4. FGS was used on the combine as a joint project with Agriculture Information Technologies for harvesting grain during 1993 and is being used in 1994.
   a) The combine-FGS package was used on the SDSU/Dakota Lakes Research Unit at Pierre, SD on 9/30/93 thru 10/20/93. A profile of field data is attached.
   b) The combine-FGS package was used on Agriculture Information Technologies research unit at Iroquois, SD.

For both studies, GPS monitoring along with yield and moisture were recorded and post processed with soil and nutrient data maps. Also, at both sites comparisons will be made between yield monitor types. This info is being analyzed and summarized. Presentations were made in March.
Presented Results:

Following the pioneering work and methodology of Linsley and Bauer (1929), two 80 acre fields in central South Dakota were site specific farmed. The fields were first grided on a 200 ft by 200 ft grid, using a differential Global Positioning Satellite Receiver. Soil samples were collected (~15 subsamples within 20 ft. of grid center) and analyzed using accepted commercial soil testing analysis procedures. Geostatistical analysis was accomplished to develop iso-antecedent Nitrogen, Phosphorous and Potassium maps of the field. Only nitrogen was studied and varied in this experiment. The field was then grided into 270 ft by 270 ft field cells. These cells were fertilized with nitrogen in three different ways. A third of these cells were fertilized conventionally (100 lb/acre). The middle third were fertilized to develop yield response curves (0, 50, 100, 150 and 200 lb/acre). The last third of the plots were fertilized site specifically (yield goal 100 bu/acre) with the soil test antecedent nitrogen from the iso-maps subtracted from the recommended nitrogen amount to result in a fertilizer recommendation. Results of this study will be discussed in the poster.

2s5. The grant timeline has been extended to 11/95. Task #2 has being extended, where the harvesting system was scheduled for the 1994 harvest season. Updated hardware and software were included and tested. Results have been reported.

2s6. This task is complete.

Task 3: Modify present chemical application equipment to more properly dispense chemicals used in farm productivity. FGS has already been moderately successfully employed with chemical application equipment, however, present equipment has a major shortcoming in manifold design. The task is to modify the sprayer manifold, employ FGS and to demonstrate a workable system.

1. Buy sprayer and manifold, modify and assemble.
2. Assemble sprayer system with FGS package.
3. Benchtop test sprayer and prepare field system.

STEPS OF PROGRESS FOR TASK 3:

3s1. The design of a sprayer with a modified manifold has been completed. Components were specified. Mr. Rod Fischer has spent considerable time toward completing the assembly of chemical application equipment.

3s2. The sprayer system is field ready - the sprayer was used in chemical application during the spring and summer on both the ARS farm and the SDSU Agronomy lands.
3s3. The sprayer manifold and necessary system components have been connected to FGS and bench testing is continuing, plus field testing has taken place. Results were presented in March.

3s4. This task is complete.

Task 4: Test and demonstrate FGS with modified chemical application equipment.

4s1. Coordination continually occurs with the Plant Science Department and Agronomy Farms for selecting times, designating fields and locations, arranging for chemicals and laying out system operation to test and demonstrate FGS with the modified chemical application equipment. Actual field use occurred in April and May of 1993.

4s2. The sprayer, equipped with the modified manifold, was used in October on the SDSU Agronomy research units for liquid application. Results for fall tests were presented at the 2nd International Conference on Site-Specific Management for Agricultural Systems, March 28-30, 1994 in the Twin Cities.

Results:

With farm implementation of GPS Technology chemical spray rates will be varied to meet the requirements of a specific field position. This technology along with on-the-go spot spraying is replacing the common practice of applying a spray mix to a field at an average rate. Instead the spray application rate is changed on-the-go with the use of direct injection chemical units. Direct injection units hold the chemical concentrate in a factory supplied container. The carrier (water) is held in a second container. This allows the applicator to spray with minimum exposure to the chemical. When the operator is finished with a field any remaining concentrate can be returned to the manufacturer. This is a more environmentally sound practice than mixing a chemical solution with water in a single tank and having the potential for leftover spray mixture.

A significant concern when implementing this technology is the lapse time that results from the distance that the concentrate must travel from its source to the sprayer nozzles. Consequently, when the chemical injection rate changes, chemical application rates will lag by the above mentioned time offset. The poster illustrates a method to minimize the lag time error associated with a singular applied chemical (one injection system with water as the carrier). A change in the manifold system was made that enables a direct injection system to be used with reduced lag time. The system utilizes a small holding tank and uses limit switches for refilling.
4s3. Results for sprayer testing were presented at the 1994 ASME Region VII Technical Conference under the title of 'An Engineering System to Vary Flow Rate and Limit Machine Lapse Time'.

4s4. System results were presented by Mr. John Oolman at the ION GPS-94 Student Paper Competition in Austin, Texas during August, 1994.

4s5. This task is complete.

Task 5: Prepare final report:

5s1. Information is being gathered and compiled to go toward the final report.

5s2. This task is complete.

ADDITIONAL ITEMS OF EFFORT AND PROGRESS:

A. A support arrangement involving system trials, use of equipment and a sharing of technology has been put in place. This is a great opportunity to test and demonstrate FGS in conjunction with a nationally-based company involved in crop production at the producer's level (a key company location is at Iroquois, SD approximately 55 miles from Brookings). A grant has been approved with the South Dakota Governor's Office of Economic Development via the Center for Innovation, Technology and Entrepreneurship and Ag Info Tech of Iroquois, SD.

B. An abstract had been forwarded to present FGS at the 'Biostress Symposia' for April-May, 1993. Presentation was made on May 24th.

C. A new member joined our research team. Dr. Dan Humburg of the Agricultural Engineering Department of South Dakota State University has been doing research in the area of machine design and machine vision. He'll put this expertise toward possible sensory and system employment utilizing FGS and information transfer and equipment control.

D. An article was prepared for the "IMPULSE" explaining the details and progress of the project. The "IMPULSE" is an informational journal of the SDSU College of Engineering with the next issue being published late summer.

E. Mr. Jack Aellen visited our site on 7/8 - 7/9/93. The visit was an opportunity to exchange significant information plus Mr. Aellen has continued to forward additional, quite beneficial information.

F. Ag Info Tech and SDSU researchers, as a team, have forwarded a grant proposal to the Small Business Initiative Research fund.
G. Further discussion on our research, system and findings are occurring with commercial assemblers and distributors in both Sioux Falls, SD and Minneapolis, MN.

H. Mr. Joe Schumacher attended the North Central Research Committee on Site Specific Farming under the CSRS/USDA Cooperative States Research Service/Dec. 2-4, 1993 in Kalamazoo, MI.
   * discussion on yield monitors
   * GPS receivers and accuracy
   * technology advances
   * environmental issues and equipment design
   * soil management and crop efficiencies
   * exchange of state reports
(A summary of this meeting was published by the journal of 'Farm Industry News').

I. Abstracts and presentations were delivered at the 2nd International Management for Agricultural Systems on March 28-30, 1994 in Minneapolis, MN with the University of Minnesota.

J. Presentation and discussion of project and related technologies occurred during the 43rd Annual Soil and Moisture Clinic with SD Association of SCS and SDSU in November, 1993.

K. Presentation on the project was given at the 1st Annual Biostress Poster Session on 3/11/94.

L. Mr. Joe Schumacher, Mr. John Oolman and Dr. Dan Humburg attended the SDSU/University of Nebraska "Geostatistics" workshop during May, 1994.

M. Details of our project were released to the general public/media by Dr. Gregg Carlson of the SDSU Plant Science Department with articles in the Sioux Falls Argus Leader and the Brookings Register.

N. Details and outcome statements were released with the "South Dakota Farm & Home AES Research: within an article entitled: "Global Positioning Satellites: Signals from space to the field".

O. Mr. Tim Aughenbaugh of Ag Info Tech, Iroquois, SD our commercial partner presented details and system specs at the Lake Area Tech/BASF Demo Center, Watertown, SD on August 24, 1994.

P. A second CITE grant entitled "AIT Site Specific Solutions for Economic Productivity" has been prepared, undergone on-campus review and has been forwarded. The identified amount is $77,095.

Q. System results were presented at the South Dakota Irrigators Conference via the SDSU Cooperative Extensive Service and the SD Irrigators Association on December 6 and 7 in Mitchell, SD.
R. System and field results were presented by Mr. Joe Schumacher with a presentation entitled "Site Specific Farming in the 21st Century" at the 44th Annual Soil and Moisture Clinic at Brookings, SD on November 13-15, 1994.

S. The use and continual expansion of this technology was further explained within an article entitled 'Going High-Tech On The Farm', South Dakota High Liner Magazine, Feb. 95 Issue. Mr. Tim Aughenbaugh of AIT, Iroquois, SD, our commercial partner was featured.

T. Field Grid Sense was demonstrated and displayed at the South Dakota Space Day on April 6, 1995 in Pierre, SD.

U. Information and methodologies involving precision farming and 'Field Grid Sense' techniques have gained tremendous interest. Systems are in use. Results and discussions on the subject were presented in several settings:

- 'Conference to examine new space-age farming' in the "Green Sheet" publication, Aberdeen, SD.
- 'Farming from the Sky', article: Brookings Register.
- "GPS Promises Profit While Easing Environmental Concerns'

V. See "Final Outcome Summary"
December 15, 1995

The DOE grant for Field Grid Sense has lead to numerous positive results. The grant has contributed to research and concepts presented at numerous public presentations as well as in popular agricultural magazines, newspaper articles and professional journal publications. The Field Grid Sense project was one of the pioneers in precision farming technology and its existence has permitted the transfer of information, concepts and technology to the public on a national as well as on a regional basis. Precision farming is gaining acceptance as a methodology for management practices in the United States and Worldwide. The incorporation of proper precision farming practices will lead to improved management of energy intensive agricultural fertilizer inputs as well as improvement in the production of energy related agricultural products such as corn ethanol. Work begun under the precision farming grant, Field Grid Sense, is continuing at South Dakota State University with Projects involving the Plant Science Department, SDSU Remote Sensing and NASA, SDSU Engineering College, Northern Grains Insect Agricultural Research Service Unit, State Ag Experiment Stations, local farmers and work being done with the NCR-180 Precision Farming Group which involves discussions and interactions at a national level with Land Grant Universities, Industry, Ag producers and governmental agencies.

In concluding, I want to express my gratitude for the opportunity which the DOE inventions program has permitted. I believe it has made a significant contribution toward improved use of energy related inputs in agriculture as well as in the production of energy related farm crops.

Sincerely,

Joseph A. Schumacher
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