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DEVELOPMENT OF LAND LEVELING EQUIPMENT BASED ON GNSS

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Abstract. An attitude adjustable land leveling equipment was designed. The reference elevation of the land to be leveled was generated based on the topographic data which was acquired by the RTK-GNSS technology. The blade lifting mechanism was controlled by comparing the reference elevation and the real-time blade's elevation and attitude data which was obtained by the dual antenna GNSS receiver and as a result the land leveling operation was implemented. A new algorithm using the electro-hydraulic proportional control technology which can control the blade's height accurately was also raised. The experiment shows that the GNSS land leveling equipment can have a good land leveling quality, and the efficiency of the land leveling operation could also be improved.

Keywords. *Land leveling, GNSS, Electro-hydraulic proportional control, Attitude data acquisition, Leveling result evaluation*

Introduction

High land leveling quality is necessary for modern agriculture and also is primary and key for water-saving irrigation. As the last step for land consolidation, land leveling quality decides the quality of land which is consolidate.

The laser control land leveling technology brings the widely used of laser land leveling equipment. The accuracy and efficiency of lend leveling operation is large improved compared with traditional equipment. But the problems such as the limited operating range, difference of operating plane, error enlarged in large operating area and the weak environment adaptability which the laser land leveling equipment has hinder the land leveling operation's development. The GNSS which contains the GPS, GLONASS, BDS and Galileo can offer the all-weather elevation data. The RTK-GNSS technology use the carrier phase solution can output the evaluation data with 20mm+2ppm accuracy, which can meet the demand of land leveling operation.

The first one to use the RTK-GNSS technology in the land leveling technology is the construction machinery. Trimble and Topcon developed their GNSS land leveling control system respectively in the grader. After the widely used in construction machinery, Trimble develop the GNSS land leveling module in their agricultural integrated control system, which can level the land with the fine quality. But the existing GNSS land leveling equipment control their blade lifting mechanism as the traditional laser land leveler do with on-off control method, and as a result, in the actual land leveling operation, the phenomenon which the equipment the scraper the soil out of their ability is often appears due to lack of blade lifting mechanism's accurate control, and the efficiency of the land leveling operation is influenced.

Considering the problem list above, a new algorithm which can control the blade lifting mechanism's accurately is raised and it can offer the a new way to the intelligent control of land leveling equipment.

DESIGN OF SYSTEM

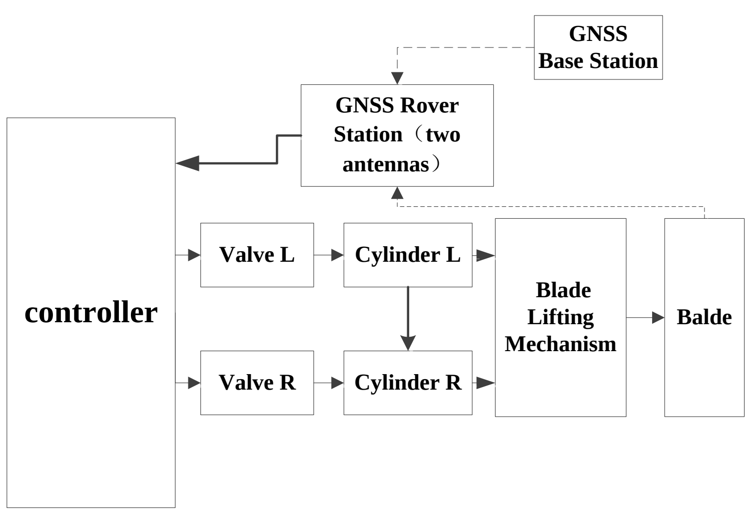


Fig. 1 Principle of GNSS land leveling equipment

Principle of GNSS land leveling equipment

The principle of GNSS land leveling equipment is shown as Fig.1. The height and attitude control of the GNSS land leveling equipment is realize by the control system adjusting the stroke of cylinder of the blade lifting mechanism according to the elevation and roll angle data acquired by the GNSS rover station with two antennas installed in a fixed distance on the top of blade. During the land leveling operation, the equipment can level the land to a plane or inclined terrain according to the actual circumstance.

Mechanical design of the GNSS land leveling equipment

Mechanism Design is the key for the land equipment to work smoothly. In this paper the leveling mechanism is mounted with the tractor using hitch which can adapt the pitch angle of the whole equipment. The mechanism of the GNSS land equipment is shown in picture 1. The blade lifting mechanism is controlled by two hydraulic cylinders, which can operate the left and right side of the mechanism respectively.

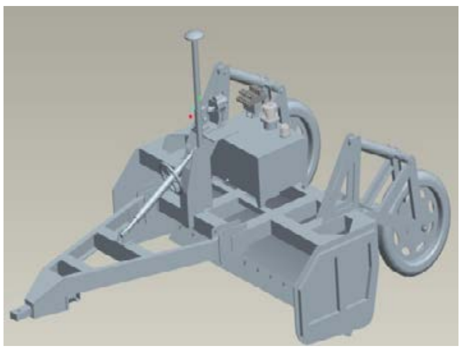


Fig. 1 Mechanical structure of GNSS land leveling equipment

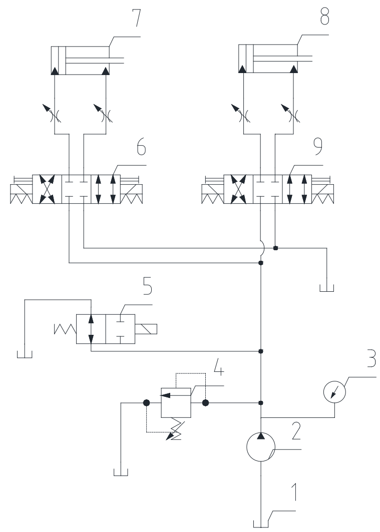


Fig. 2 Hydraulic system of GNSS land leveling equipment

1. reservoir, 2.geer pump, 3.pressure gage, 4.pressure relief valve, 5. electromagnetic relief valve, 6.left electrohydraulic proportional reversing valve, 7.left cylinder, 8.right cylinder, 9.right electrohydraulic proportional reversing valve

In order to have the accurate control the two cylinders respectively, the proper hydraulic system have to be designed. The performance of the hydraulic system is lowered due to the heat generated when the system works, so in this paper the strategy loading the system when the leveling operation done is applied. As Figure2 shows, in the idle mode, the hydraulic system unloads by the left position of the electromagnetic relief valve, and there is no pressure in the system. During the operative mode, the electromagnetic relief valve is powered, and the pressure is setup, the height and attitude accurate adjustment is realized by controlling the two electrohydraulic proportional reversing valves respectively.

Control system design of the GNSS land leveling equipment

The acquisition of attitude data

There are two methods to acquire the attitude data of the blade. One is using the attitude sensor. This method is low-cost, but is not suitably using at the land leveling equipment due to the high vibration frequency. The other one is using the two antenna GNSS receiver. This method can get the stable roll angle output.

The acquisition of attitude data

The previous land leveling equipment uses the bang-bang control method to control the blade lifting mechanism. This method compares the reference elevation and the measured elevation. When the measured elevation is higher than the reference elevation, the blade is lowered, and when the measured elevation is lower than the reference elevation, the blade is lifted. If the difference value is greater, the height of blade often falls too much and as a result the tractor cannot draw the equipment.

A new method to control the height of blade accurately is designed in this paper. As the Fig.4(a) and Fig.4(b) shows, when the blade is on the ground, the length of the lifting mechanism is L, the radius of the land wheel is R, and H is the height of blade.

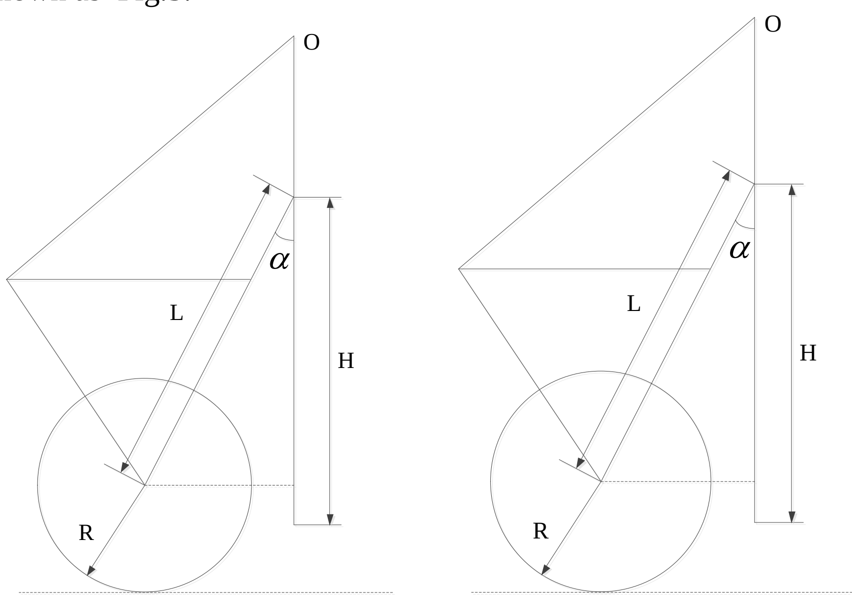
As the cylinder of the lifting mechanism is extended, the angle α becomes smaller, as a result, the blade is lifted, and the height H_1 is:

$$H_1 = L\cos\alpha + R - H \tag{1}$$

As the cylinder of the lifting mechanism is shortened, the angle α becomes larger, as a result, the blade is lowered, and the height H_2 is:

$$H_2 = H - L\cos\theta_2 - R \tag{2}$$

An angle sensor is installed, and by changing the stroke of cylinders the angle could be controlled, as a result the accurate control of the blade height could be realized. The control system block diagram is shown as Fig.5.



(a) the cylinder is extended (b) the cylinder is shortened

Fig. 3 Blazer lifting mechanism when the cylinder is extended

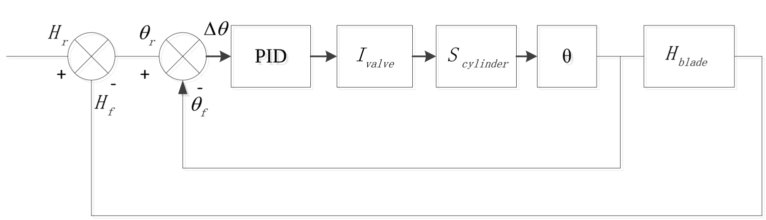


Fig. 5 Control system of blade lifting mechanism

In the diagram, H_r is the reference elevation, H_f is the measured elevation, θ_r is the reference angle, θ_f is the measured angle, I_{valve} is the current powered to the proportional reversing valve, and $S_{cylinder}$ is the stroke of the cylinder.

Reference elevation of the land leveling operation

There are many approaches to acquire the reference elevation, such as arithmetic average method, weighted average method, and kriging interpolation method. Kriging interpolation is a common used interpolation method is geo-science. The equation of kriging interpolation is:

$$Z_j = \sum_{i=1}^{n} \lambda_i Z_i \qquad (3).$$

In this equation, λ_i is the weighting factor with the equation $\sum_{i=1}^{n} \lambda_i = 1$, Z_i is the discrete points' elevation, and Z_j is the interpolation value. In this paper the software Surfer is used for the kriging interpolation, and the result is averaged to get the reference elevation.

Control system for land leveling operation

A self-developed controller RC-3 which has lots of control interface such as 8 PWM/Switch output,2 analog input,2 RS232 interfaces and a CAN interface is used in this paper as the Fig.6 shows.

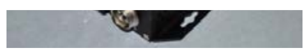


Fig. 6 RC-3 controller

The control terminal is a specialized vehicle-mounted terminal which can analyze the GNSS input, compute the reference elevation, and display the relevant information. CAN bus is used for communication between the terminal and the controller to transfer the reference elevation, real-time land elevation and the roll angle of the blade.

All these messages are received by the controller and the proportional reversing valves are controlled separately to adjust the blade's height and attitude. The control system's control flow chart is shown as Fig.7

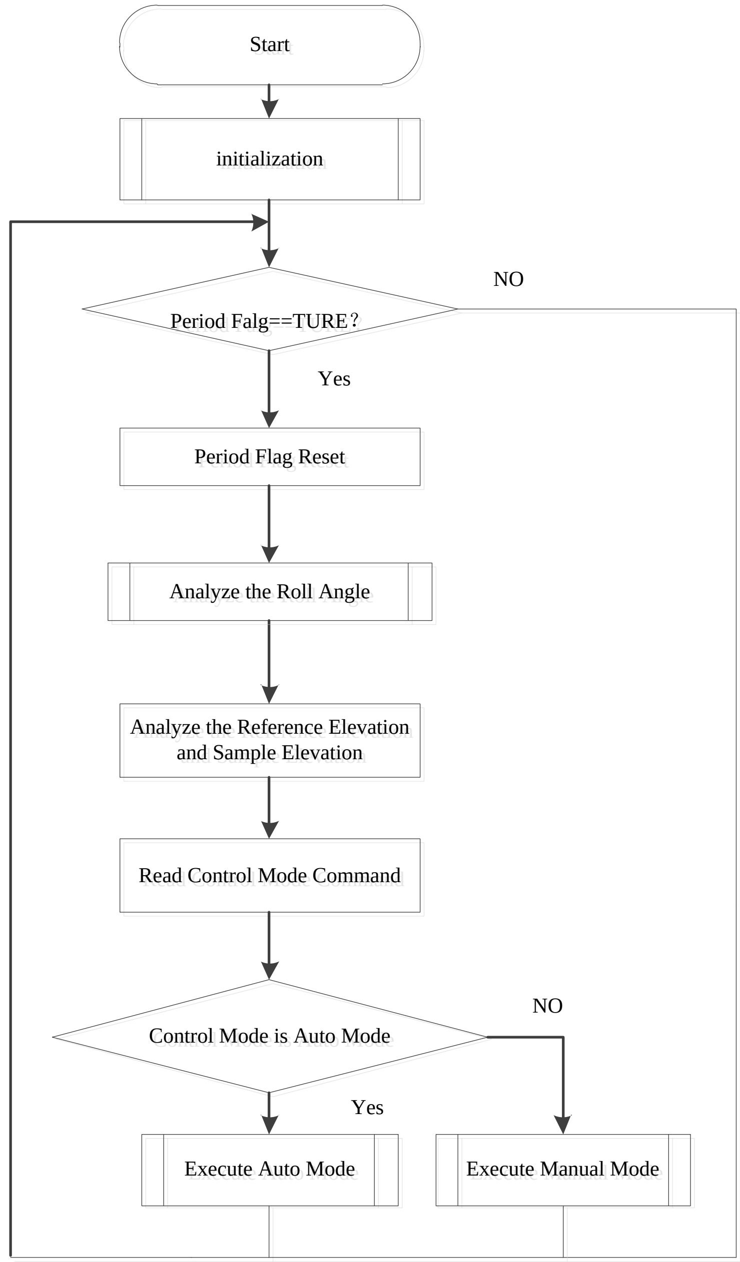


Fig.7 Flow chart of monitor module

TESTING AND DATA ANALYSIS

Experiment procedure

Land select and equipment prepare: An area of 30m x 30m experiment land in National precision agriculture demonstration base is selected for the land leveling operation. Before the leveling, the land should have a rotary tillage operation. The GNSS receiver from the Compass Navigation company can have an 20mm ± 2ppm accuracy and 10HZ output frequency.

Land leveling operation and data acquisition: Before the land leveling operation, lift the blade to the top of its limit, and record the height H. Drive the tractor along the route shown in Fig.8 to get the raw topographic data. After the land leveling operation, such work should be done again.

Raw topographic data processing: Subtracting the height H, the land elevation could be calculated and the topographic map could be generated.

Leveling result evaluation

There are 2 standards to evaluate the result of land leveling operation. One is the standard deviation S_d between reference elevation and sample elevation. It can reflect the evenness of the land. The equation to calculate the S_d is:

$$S_d = \sqrt{\sum_{i=1}^{n} (h_i - \bar{h})^2 / (n-1)} \quad (4).$$

In this equation, h_i is sample elevation, $\bar{h}$ is reference elevation, and n is the number of sample points.

The other standard is the percentage α of difference value $|h_i - \bar{h}|$ which is smaller than a fix value between the sample elevation and reference elevation. It can reflect the evenness distribution.

Fig.9 and Fig.10 is the topographic map before and after the leveling operation. Table 1 is the evenness data according to the two standards list above. From table 1 we can find that after 2 hours leveling operation, the S_d is down to 1.26cm from 7.44cm, and the α of $|h_i - \bar{h}|$<3cm is up to 97.34% from 23.26%. To have the same result, the traditional laser and GNSS leveling equipment would cost 2.5 hours. The efficiency of the land leveling operation rises by 25%.

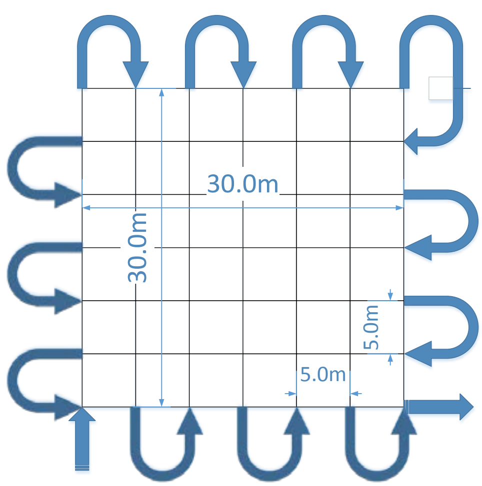


Fig.8 Routing of land measurement

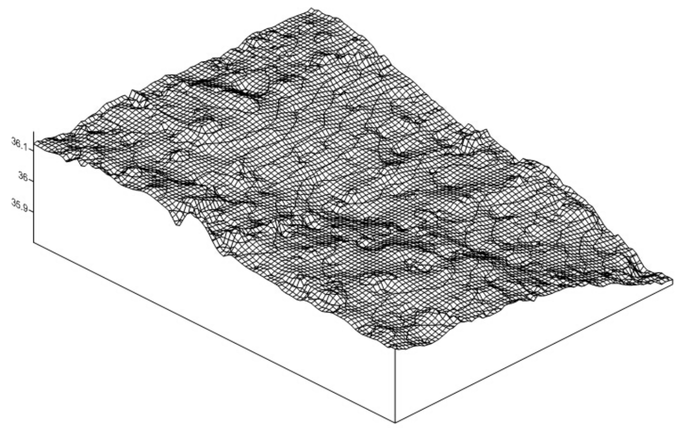


Fig.9 Routing of land measurement

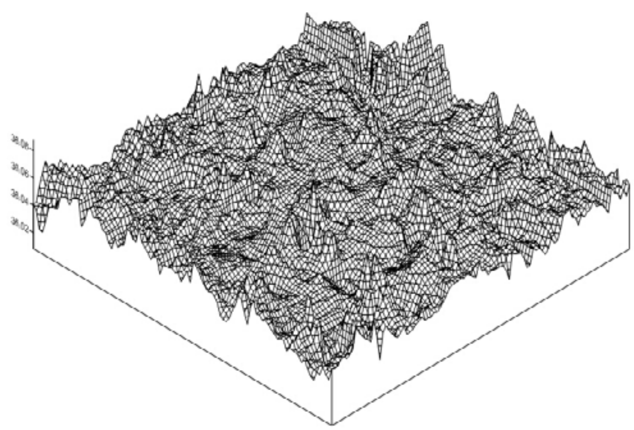


Fig.10 Routing of land measurement

Table 1. Result of GNSS land leveler

	S_d (cm)	Max($\left\|h-\bar{h}\right\|$)(cm)	α (percent of $\left\|h_i-\bar{h}\right\| < 3cm$)
Before leveling operation	7.44	25.31	23.26%
After leveling operation	1.26	5.5	97.34%

Conclusion or Summary

(1)A RTK-GNSS technology based new land leveling equipment is developed.

(2) A new blade height control method is raised to substitute the previous bang-bang control method used by the previous laser and GNSS leveling equipment.

(3)The experiment shows that the GNSS land leveling equipment can have a good land leveling quality, and the efficiency of the land leveling operation could also be improved.

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