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Spatial Information Analysis of Grass-Land Using Information Technology

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Abstract: The objective of this research is to develop grass-land reclamation criteria using an information technology. To develop the grass-land reclamation criteria, the terrain of grass-land was resolved into the spatial frequency by discrete Fourier transform (DFT) using the digital elevation model (DEM). The DEM was generated by the measurements before and after the grass-land reclamation. Then, the geographical features and the spatial frequency information in the same field were compared. To make a GIS map based on terrain information, absolute location of the grass-land surface is essential. To measure the elevation efficiently, a tractor-based survey system was developed. A farm tractor equipped with a real-time kinematical global positioning system (RTK-GPS) and an inertial measurement unit (IMU) was used. As a result, the spatial frequency which shows a large change was in the range of 0.02～0.05[1/m]. Moreover, smooth geographical features of grass-land was obtained by deleting the spatial frequency of 0.02～0.05[1/m] from the actual geographical features before the grass-land reclamation.

1. INTRODUCTION

An information technology (IT) is a key technology of agriculture in the 21st century. It has been applied to a production management and marketing activities of agricultural products; for instance a digital agriculture, a digital marketing, and a digital management and so on. IT doubtlessly contributes much to agriculture and rural development. Competitive, safe and sustainable agricultural production can be realized with an improvement of farm management, risk management and information transfer.

Japan agriculture is confronted with labor shortage and aging of farmers. One possible solution to these problems is the use of advanced production management information which may save a labor and reduce the cost of the agricultural products. Advanced information management can be achieved by applying information technology (IT), such as a geographic information system (GIS) and a global positioning system (GPS). A GIS is a powerful tool for automating cartography and for analysis of both geographical and attribute information on places. The historical development of the GIS indicates that much of it stems from thematic cartography and overlay functions of thematic maps in urban and regional planning prior to 1960, and from computer-assisted cartography of the 1960s. GIS has been applied in various fields including geography, spatial sciences, agriculture, civil engineering, and urban planning; therefore, none of these fields can lay claim to the home field of GIS. Barbari *et al.* (2006) reported use of global positioning and geographical information system in the management of extensive cattle grazing. This research aimed at verifying the possible use of GPS and GIS technologies to understand the behaviour of domestic and wild animals bred for extensive grazing. Cugati *et al*. (2003) developed an automated fertilizer applicator for tree crops. The system consisted of an input module for GPS and real-time sensor data acquisition, a decision module for calculating the optimal quantity and speed pattern for a fertilizer, and an output module to regulate the fertilizer application rate.

Recently, large machinery is introduced to the grass harvesting in a dairy farming in Japan. To improve the working efficiency of the large machinery, it is necessary to modify the irregularities of the grass-land terrain. However, there are no effective criteria for modification of irregularities of the grass-land. Seeruttun and Crossley (1997) reported the used of digital terrain modelling (DTM) and computer aided design (CAD) for farm planning for mechanical harvest of sugar cane. In this study, categorization of fields by magnitude of slope was considered: below 12% (suitable for mechanized harvest), above 18% (very difficult to harvest mechanically) and those with slopes between 12 and 18% which could be harvested mechanically only after land improvement. Exposure to whole-body vibration (WBV) may cause health problem, e.g. lumbago. The risk depends on intensity and duration of vibration. Exposure to WBV in vehicles varies due to several factors as the vehicle type, the terrain condition, the driver, the speed, etc. (Rehn *et al*., 2005). Kang *et al*. (2007) developed classification method for a grass-land. It is based on a terrain information and an acceleration information. The area where the land needs reclamation was identified automatically by a discriminant analysis using explanation variable of synthetic vector and inclination angles. Sugiura *et al*. (2004) developed remote sensing system that can generate a 3-dimensional field map regarding crop status and field information using a multi-spectral image sensor and laser range finder mounted on the unmanned helicopter. This system could generate a topographic map with 9cm error, and 3-dimensional image map with spatial error of 41-cm. Lee *et al*. (2002) developed a silage yield mapping system, which included a GPS, load cells, a moisture sensor and a Bluetooth wireless communication module.

The objective of this research is to develop a grass-land reclamation criterion using an information technology. To develop the grass-land reclamation criteria, the terrain of grass-land was resolved into the spatial frequency by discrete Fourier transform (DFT) using the digital elevation model (DEM).

2. MATERIALS AND METHOD

2.1 Materials

Figure 1 shows the schematic diagram of a farm tractor-based grass-land survey system. A John Deer 6410 78-kW farm tractor was used. This tractor was owned by a farmer and not specially designed for a survey. To generate a GIS map based on spatial information, vehicle location is essential; a real-time kinematic global positioning system (RTK-GPS), Trimble MS750 with a virtual reference station (VRS) provided absolute vehicle position with an error of +/- 2 cm and altitude of test grass-land were used. An inertial measurement unit (IMU) JCS7401A (Japan Aviation Electronics Industry) was used for correcting vehicle posture data such as roll, pitch and yaw angle. Obtained position data was corrected by using the inclination angle of the tractor. The VRS-RTK-GPS and IMU were connected to a laptop personal computer (PC) with RS-232 serial cables.

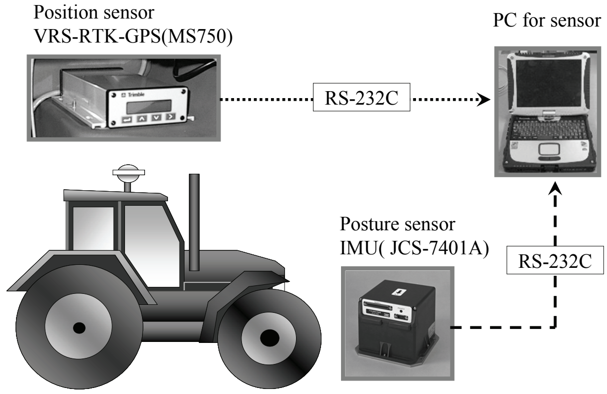


Figure.1 Schematic diagram of a farm tractor-based grass-land survey system

2.2 Method

Field tests were conducted at the grass-land of Nakashibetsu, Hokkaido in Japan. The area of the field was 3.2 ha as shown in Fig. 2. Small round dots in a map show the location of measurements. An operator drove the tractor in an usual path for grass harvesting. During the harvesting, vehicle location and inclination were simultaneously measured and recorded on the hard-disk of a PC in 5Hz. The tractor's average running speed was 3.2 m/s. Time period of measurement was 110 min with 68 travels.

Topographic data was utilized for developing a grass-land reclamation criterion method. To develop a grass-land reclamation criterion, first, the area where an operator felt uncomfortable and dangerous to drive was identified by an interview. From unevenly scattered altitude data obtained by the tractor-based survey system was transformed into 1 x 1 m grid mesh ESRI Arc GIS 9.2 was used for resampling process.

After making a DTM model, discrete Fourier transform (DFT) was used to analyze the topographic data.

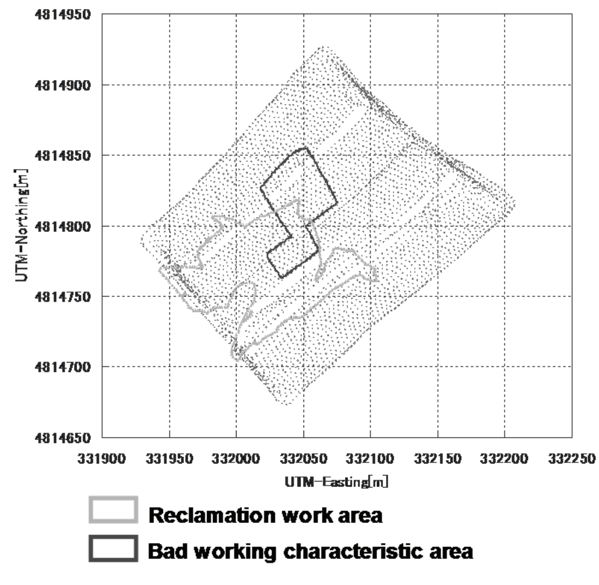


Figure.2 Test field on the grass-land and reclamation area.

2.3 Discrete Fourier Transform (DFT) of topographic data

The Fourier transform is usually used to express the characteristic of any waves. The data in the time domain is transformed into the frequency domain data. In this research, the two-dimensional Discrete Fourier Transform (DFT) was used. The equation of the discrete Fourier transform is given in (1). And the equation of the Inverse Discrete Fourier Transform (IDFT) is given in (2).

$$F(k,l) = \sum_{x=0}^{X-1}\sum_{y=0}^{Y-1} f(x,y) W_X^{\ xk} W_Y^{\ yl} \qquad (1)$$

$$(\ k = 0,1,\cdots,X-1 \qquad l = 0,1,\cdots,Y-1)$$

$$f(x,y) = \frac{1}{XY}\sum_{l=0}^{X-1}\sum_{k=0}^{Y-1} F(k,l) W_X^{\ -xk} W_Y^{\ -yl} \qquad (2)$$

$$(\ x = 0,1,\cdots,X-1 \qquad y = 0,1,\cdots,Y-1)$$

where $W_X = e^{(-2\pi i)/X}$ and $W_Y = e^{(-2\pi i)/Y}$

To apply the two dimensional DFT, the data should be a rectanglar matrix. In this research, the center area of the field was extracted. In Fig 3, a square region shows a sampling area. The width and the height of this area were 100m. This area includes a place where geographical features changed greatly by reclamation Wolfram Research, Inc. Mathematica 5.2 was used for the data processing.

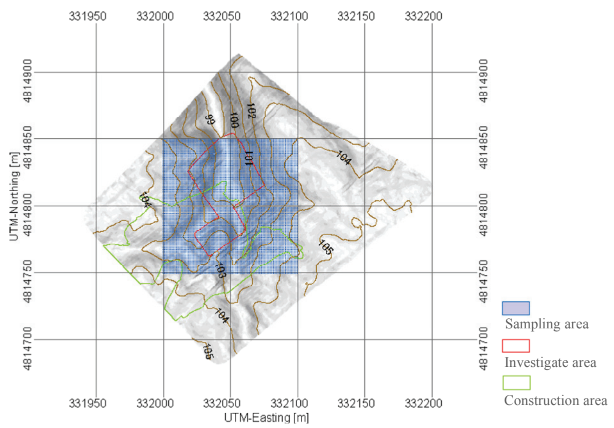
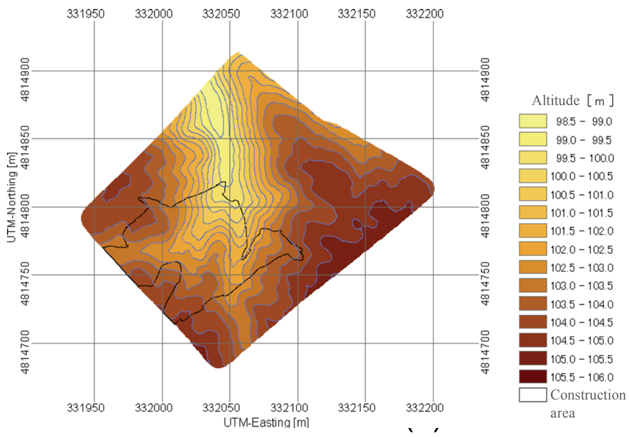


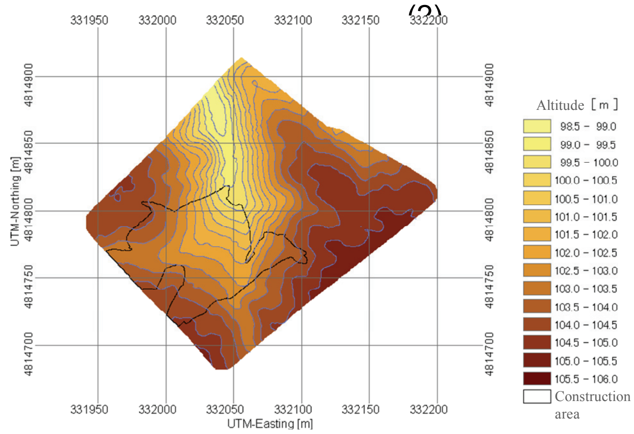
Figure 3. Data acquisition area for the discrete Fourier transform.

3. RESULT AND DISCUSSION

Figure 4 shows the topographic maps before and after the grass-land reclamation. The area enclosed with black line is reclamation area where the soil was moved and filled. The irregularity observed in Fig 4(a) was smoothed in Fig 4(b). The concave region was filled and the convex one was cut.



(a) Before the reclamation



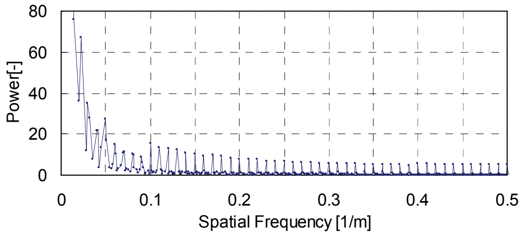
(b) After the reclamation

Figure 4. Topographic maps before and after the grass-land reclamation work.

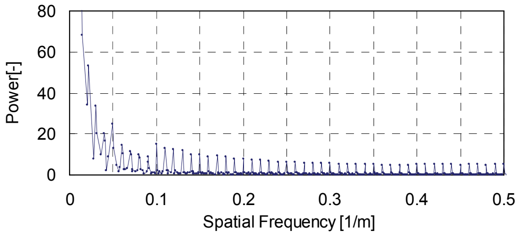
To investigate the changes of geographical features before and after reclamation in the spatial frequency domain, DFT was applied. As a result, the shape of power spectrum was changed. Figure 5 shows the spectrum difference before and after reclamation. Large difference was observed in frequency of 0.02~0.05[1/m]. It is means that the area which has this low frequency needs reclamation Therefore, the band-pass filter which cuts this low frequency of 0.02~0.05[1/m] was designed. Fig. 6(a) shows the result of band-pass filtering. Fig. 6(b) and (c) show the actual terrain of the area before and after construction. Although there are still unevenness in Fig. 6(a), the virtually filtered geographic feature resembles the actually smoothed one.

Figure 7(a) shows the elevation change by actual re reclamation work. Figure 7(b) shows the estimated elevation change by adopting DFT and IDFT. Colored area is the filled and cut area. From zero (0) horizontal line in the Fig. 7(a) and 7(b), the positive area is the cut area and negative area is the filled area. Comparing Fig. 7(a) and 7(b), the geographical feature looks similar in the area of the reclamation.

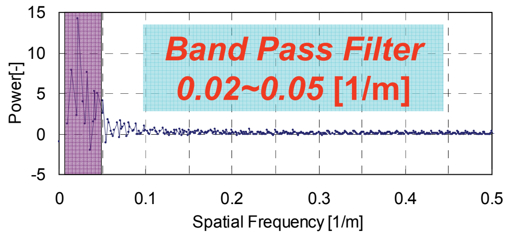
The similarity of the geographical features between Fig. 7(a) and 7(b) was examined. Fig. 8 shows the results of geographical features generated by DFT and IDFT using topographic data before the reclamation. Coefficients of determination were 0.678. And root mean squared (R.M.S.) was 0.17.



(a) Before the reclamation

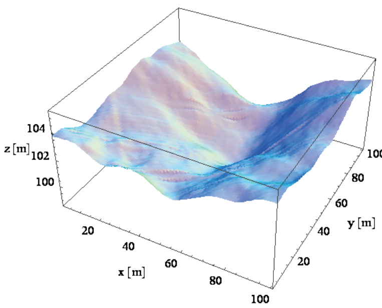


(b) After the reclamation

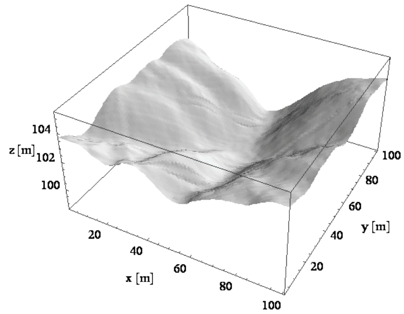


(c) Spectrum difference *before and after the reclamation*

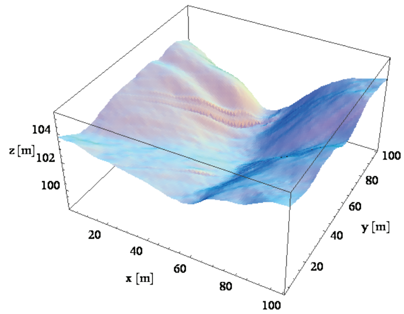
Figure 5. Spectrum difference of geographical features before and after reclamation.



(a) Band-pass filtered

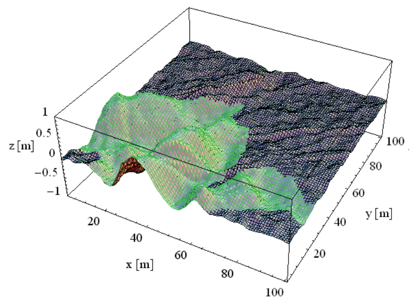


(b) Before the reclamation

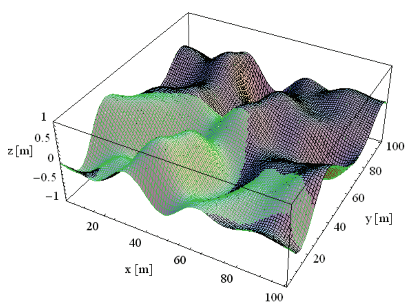


(c) After the reclamation

Figure 6. Three (3)-dimensional topographic maps of before and after the grass-land reclamation and the result of DFT and IDFT using the band-pass filter.



(a) Topographic difference before and after the reclamation



(b) Topographic difference before the reclamation and result of DFT and IDFT

Figure 7. Comparison of topographic difference on the reclamation and the result of the DFT and IDFT.

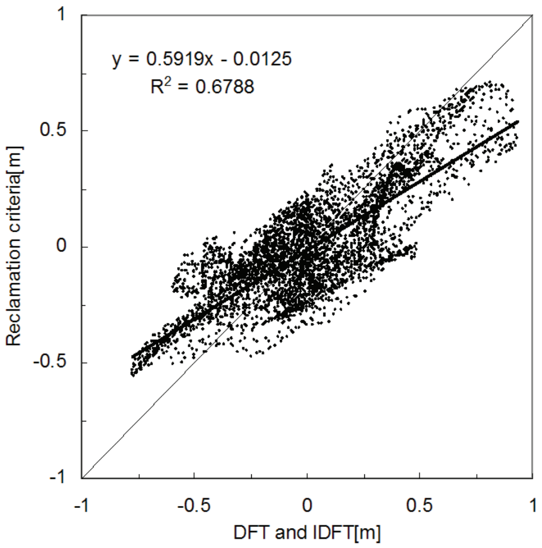


Figure 8. Prediction accuracy of geographical features generated by DFT and IDFT

4. CONCLUSIONS

This research aimed to develop grass-land reclamation criteria using an information technology. The spatial frequency with a large change of before and after grass-land reclamation was 0.02 ~ 0.05[1/m]. It is concluded that by using the band-pass filter the terrain after reclamation can be predicted.

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