Grassland utilization estimation method and system based on environmental sense

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RESEARCH

Grassland utilization estimation method and system based on environmental sense

Chuanjian Wang[1,3], Dong Li[2,3*], Tianying Yan[2,3], Qilei Wang[2,3], Ju Wang[2,3] and Wanlong Bing[2,3]

Abstract

The utilization of natural grassland is an important part of grazing animal husbandry. Effective monitoring and accurate estimation of the utilization of natural grassland ~~is an inevitable requirement~~ are inevitable requirements for the sustainable development of grazing animal husbandry. In order to estimate the utilization process of ~~nat-ural~~ natural grassland effectively, this paper proposes a grassland utilization estimate estimation method based on environmental sense. In this paper, the distribution of feed ~~in-take~~ intake was obtained by the GPS ~~track~~ trajectory data, and the distribution of grassland ~~bio-mass~~ biomass was obtained by the satellite remote sensing estimation model of natural grassland. The feed intake and grassland biomass are classified and compared respectively. According to the value of the two, the utilization of grassland in each region was obtained. And this study designed a grassland utilization ~~esti-mating~~ estimating system based on this estimating method and 3S technology. The results show that this method is of great significance to the rational utilization of grassland and the implementation of rotational grazing. The system can provide decision-making basis for ranchers and grassland livestock management departments to manage grazing and grassland. It enables ranchers to make reasonable and effective grazing plans, so as to make balanced utilization of grassland resources and promote the sustainable development of grazing animal husbandry.

Keywords: Grassland utilization, estimation, sense, system, GIS

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I. Introduction

Grassland is not only an important ecological barrier for the earth, but also the material basis for the livestock production in pastoral areas [1]. China's natural grassland is about $4 \times 10^8 hm^2$, accounting for 41.7 % of the country's land area [2]. However, 90% of China's grassland has different extent of degradation [3]. In the mean time, grassland degradation has become a serious environmental and economic problem all over the world [4][5]. An important cause of grassland degradation is overgrazing [6][7][8][9][10][11]. It has severely hindered the development of animal husbandry, reduced the income of herdsmen, and caused significant impacts on the ecological balance. Therefore, regular and effective estimation of natural grassland utilization plays an important role in promoting the sustainable development of grazing animal husbandry.

~~Acommonly~~ In the current studies, most researchers used grassland utilization estimation method is based on the temporal and spatial evolution model. This model uses Global Positioning System (GPS) sense to obtain grazing behaviors and these grazing behaviors can be used to indirectly estimate the grassland utilization. ~~For example, Akasbi, Dengler, and Wang~~ Some researchers used GPS collar to record the grazing ~~track~~ trajectory of ~~herds~~ the herd at a certain time interval and ~~calculated the number of herds in each cell by grid method~~ researchered feeding behaviors of the herd, so as to obtain the grazing situation of ~~herds~~ the herd. Akasbi et al.

[12] studied the large-scale migration rules of herd, and then analyzed the factors affecting the migration direction of herd. But they only analyzed the factors that affect the migration of the herd. Wang et al. [13] calculated the number of herd in each cell by grid method, so as to obtain the grazing situation of the herd. Lin et al. [14] used GPS to record the grazing ~~track~~ trajectory of herds, and manually recorded the grazing behavior of sheep. They studied the influence of different grazing intensity on walking distance, eating time and organic matter intake of sheep. Wang et al. [15] obtained the spatiotemporal distribution information of sheep under different stocking rates by GPS collar. They studied the spatiotemporal distribution characteristics of sheep's grazing behaviors and its relationship with grassland environment by using spatial analysis technology. However, the grassland utilization couldn't be estimated really under different stocking rates. These studies focused on the feeding behaviors of the herd. The distribution of grazing intensity and feed intake was obtained by counting the number of GPS points per unit area. However, without considering the spatial heterogeneity of vegetation, counting number is not an accurate estimation [16][17] and therefore cannot directly obtain the vegetation changes during grazing. This makes it difficult to effectively estimate the utilization of grassland.

Another way of estimating grassland utilization is by using Remote Sensing (RS) technology. Fei Li et al. [18] analyzed the impact of grazing on the physical characteristics of vegetation, and quantified the biomass threshold of grazing intensity level (no grazing, light grazing, moderate grazing and severe grazing) through the biomass calculated by remote sensing spectrum. Feng and Zhao [19] monitored grazing intensity by integrating remote sensing observations into the central ecosystem model. Franke et al. [20] used the method of the statistics based on time series data and the context to estimate the grassland utilization intensity of the management plot. The evaluation method had higher requirements for the date and season of remote sensing information collection, and higher requirements for data quality. In these studies, most researchers only used remote sensing images to estimate the impact of grazing on the biophysical properties of vegetation [21], but basically ignore the continuous and potential different effects of grazing behavior over time. In the above two methods, the factors considered in estimating grassland utilization are relatively single. It is difficult to comprehensively estimate the grassland utilization. The utilization process of natural grassland is a process of continuous interaction between grazing behavior and grassland vegetation growth. Therefore, grazing behavior and vegetation growth should be considered in the estimation of natural grassland utilization.

In terms of system, Wu et al. [22] developed a grassland resource information system based on 3S technology. The system provided reliable data support for grassland management ~~and utilization~~ in Western China. Howerver, it need to make statistics of the actual carrying capacity and compare it with the predicted carrying capacity for monitoring. Wei et al. [23] established the system database of grassland and the monitoring and prediction system of grassland animal husbandry in northern China, which can quickly obtain all kinds of grassland monitoring and prediction data. Although the existing grassland monitoring systems have realized the monitoring function of various grassland resources, these studies have rarely achieved the function of grassland utilization estimation.

With the continuous improvement of service quality in the cloud field and the In-ternet, technologies involving related fields are more reliable [24][25][26][27][28]. Relevant scholars have studied the offload methods of various networks (such as 5G network [29], wireless metropolitan area networks [30], Internet of things [31][32] and the prediction methods [33][34]. These methods provide great reference value for the study of this paper.

In order to overcome the drawbacks of the above works, this study proposes a new grassland utilization estimation method, based on the technology of environmental sense. Be different from existing methods, this new method considers the effects of natural grassland vegetation and grazing process on natural grassland utilization. Combined with the studies of related scholars, using GPS technology to record the trajectory of herd and calculate the feed intake of herd. The biomass of grassland can be calculated by RS technology, and then the biomass and utilization of grassland can be evaluated efficiently. The specific objectives are: 1) to calculate the feed intake of the herd and grassland biomass, and propose the estimation method of natural grassland utilization based on environmental sense; 2) to develop a grassland utilization evaluation system.

II. Data and Methods

A. Study Area

~~The utilization process of natural grassland is a process of interaction between grazing behavior and grassland vegetation growth. In this study, the interaction between natural grassland vegetation and grazing process was considered comprehensively. The GPS device was used to perceive the herd's feeding behavior, and the trajectory calculation algorithm is studied to estimate the herd's feed intake distribution. The remote sensing data of grassland was used to perceive the growth of pasture vegetation. The remote sensing estimation model was used to estimate the biomass distribution of grassland. Finally, the feed intake distribution of the herd and the biomass distribution of grassland are superimposed to estimate the utilization of the natural grassland.~~ The study area is located in the Ziniquan pasture of Shihezi City, Xinjiang production and construction corps. Its geographical location is 85°46'15.06 "E, 44°00'13.23"N and the area is about 1318km^2. This area is a low moun-tain and hilly area with an average altitude of 1000m and annual precipitation of 240-380mm . It belongs to semi-arid climate. The type of grassland belongs to the temperate desert grassland (soil desert subclass). The ranch grazing period lasts for a total of 6 months, starting in May and ending in October. The grazing sheep are Chinese Merino sheep with a total of 170 sheep.

B. Perceive Grazing Environment

The utilization process of natural grassland is a process of interaction between grazing behavior and grassland vegetation growth. In this study, the interaction between natural grassland vegetation and grazing process was considered comprehensively. The GPS device was used to perceive the herd's feeding behavior, and the trajectory calculation algorithm is studied to estimate the herd's feed intake distribution. The remote sensing data of grassland was used to perceive the growth of pasture vegetation. The remote sensing estimation model was used to estimate the biomass distribution of grassland. Finally, the feed intake distribution of the herd and the biomass distribution of grassland are superimposed to estimate the utilization of the natural grassland.

Obtain Grazing Trajectory to Perceive Grazing Behavior of the Herd

~~In this experiment, the position information was collected by collars with GPS devic-es. It was encapsulated according to the data transmission standard and sent to the server through the data communication link. The data information was parsed and stored in the SQL Server database. The data information mainly included device ID, location information and sending time, etc.~~ In this study, GT03C positioning device produced by Shenzhen gumi electronics co. LTD. was selected as the positioning terminal by comprehensively considering such factors as the quality, price, positioning accuracy, endurance capacity of GPS device. The positioning error of this device is less than $10m$ and the mass of the device is $202g$. GPS device can work normally for $72h$ when the positioning time interval is $20s$. It can work normally for $120h$ when the positioning time interval is $3min$. In this study, after considering the two factors of the fitting degree between the recorded trajectory and the real trajectory, and the endurance of GPS device, it is decided to take $3min$ as the device positioning time interval. Ten sheep were randomly selected at a time to wear positioning collars to track the grazing trajectory of the herd. The location information and attribute information collected by the device were encapsulated and processed according to the data transmission standard, and then sent to the server through the data communication link. When the server received GPS trajectory data, it parsed the data and stored the results in the location information database. Data information mainly includes device ID, latitude and longitude information, sending time, receiving time, etc.

Trajectory data were collected from July to September 2015, May to September 2016, and April to August 2017. More than 700,000 trajectory data were effectively recorded. The research object of this study was the behavior of the herd during feeding in the pasture. However, the GPS devices continuously recorded the location information of the herd. Therefore, the herd trajectory data must be preprocessed by eliminating the trajectory data in the sheepfold before calculating the feed intake of the herd.

Obtain Remote Sensing Data to Perceive Vegetation Growth

Satellite remote sensing technology is less limited by geographical factors, and can provide large scale image data. Its observations are macro and comprehensive, so it is suitable for biomass monitoring in a wide range of grasslands. UAV remote sensing technology has the advantages of low cost, high security, strong mobility, high image resolution, good timeliness and little impact by weather change, which makes up for the shortcomings of satellite remote sensing. However, the endurance of UAV is limited, so the acquired image area is limited. Therefore, this system used satellite remote sensing technology to estimate the existing biomass of grassland, and then estimated the utilization of grassland. In this study, Landsat 8 OLI satellite was used to obtain satellite remote sensing image data of the study area. Its time resolution is 16d and its spatial resolution is 30m. The Landsat 8 image data with strip No.144

and line No.29, which ~~was~~ is in good quality, cloudless, and full coverage of the study area, was selected for processing. In order to ensure the accuracy and validity of the test results, it is necessary to use the Radiometric Calibration module and the FLAASH atmospheric correction module in the ENVI5.3 software to calibrate the image before using the image.

C. Calculation Model of the Herd's Feed Intake Distribution Based on Grazing Trajectory

~~The feed intake distribution module called ArcPy package to process the data of the herd trajectory. By creating a grid and using the model of the feed intake distribution of the herds, the feed intake in different regions was calculated. The distribution maps of the feed intake in different regions were obtained. In terms of the normal grazing, there is no significant difference in the daily feed intake of the herd [35]. The greater the number of GPS points, the greater the feed intake. In this paper, the fishnet tool of ArcGIS was used to grid the study area. According to the proportion of GPS points in each grid to the total GPS points in the study area, the feed intake of the herd in each cell was calculated.~~ The utilization of grassland is closely related to the feed intake of the herd. In order to estimate the grassland utilization in the study area, it is necessary to monitor feed situation of the herd. The area with GPS points distribution is the feed area of the herd., so the more GPS points in a certain area, the greater the feed intake in that area. Some researches have shown that there is no significant difference in the total daily feed intake of the herd under normal grazing conditions[35]. Therefore, in this study, the study area was gridded firstly. And then the total daily feed intake of the herd was allocated to each cell area according to the ratio of the number of GPS points in each cell area to the total number of GPS points in the study area. Finally, the herd's feed intake in each cell area could be calculated. In order to calculate the feed intake per unit area, the area of each cell should be considered. Therefore, the daily feed intake per unit area of the herd is:

$$I = F \cdot \frac{A_i}{\sum A_i} \cdot \frac{1}{S_i} \tag{1}$$

~~Where $\sum I$ is the feed intake of the herd for N days (g/m^2), A_i is the number of GPS trajectory points in the i-th cell of the feed N days, $\sum A_i$ denotes the total GPS trajectory points of the feed N days for herd.~~ where I denotes the feed intake per unit area of the herd in one day, g/m^2. F denotes the total daily feed intake of the herd. In this study, the experimental parameter of the F denotes $170 \times 2000g$. 170 denotes that there are 170 sheep in the herd. 2000g denotes that the total daily feed intake of each sheep denotes 2000g. A_i denotes the number of GPS trajectory points in the i-th cell of a certain day; $\sum A_i$ denotes the total number of GPS trajectory points in the study area on a certain day. S_i denotes the area of the i-th cell, m^2.In practical application, because grazing is staged, the utilization of grassland should also be staged. Therefore, in order to estimate the forage feed intake of the herd over a period of time, the formula is:

$$I_n = n \cdot F \cdot \frac{C_i}{\sum C_i} \cdot \frac{1}{S_i} \tag{2}$$

where I_n denotes the feed intake per unit area of the herd in n days, g/m^2. C_i denotes the number of GPS trajectory points in the i-th cell in n days. In this research, Eq.2 was used to calculate the distribution of multi day feed intake of the herd.

~~The projection of trajectory data, grid analysis and frequency distribution statistics of trajectory points were the cores of the calculation of feed intake. They were achieved by calling the related functions of ArcPy package, such as Project_management() function, CreateFishnet_management() function, Spatial Join_analysis() function, AddField_management() and CalculateField_management() functions of ArcPy package.~~

D. Calculation Model of Grassland Biomass Distribution Based on Remote Sensing Data

Zhang Ya et al. [36] used Landsat 8 OLI remote sensing data and ground measured bio-mass data to build grassland estimation model through s tatistical analysis. The result showed that the grassland biomass of the sunny slope and shady slope had a good fitting effect with the soiladjusted vegetation index (SAVI) (sunny slope R^2=0.703, shady slope R^2=0.712). The grassland biomass was calculated:

$$B = \begin{cases} 178.71 \cdot x^2 + 97.199 \cdot x + 37.794, & \text{sunny slope} \\ 112.01 \cdot x^2 + 305.36 \cdot x - 59.296, & \text{shady slope} \end{cases} \quad (3)$$

where x is the value of RVI, and B is grassland biomass.

~~The data of the images was processed and analyzed by calling BandMath module. The distribution map of grassland biomass was obtained.~~

E. Estimation Methods of Natural Grassland Utilization of Perceiving Grazing Environment

~~The utilization process of natural grassland is a process of continuous interaction between grazing behavior and grass growth. The grass growth and grazing behavior should be considered when estimating the utilization situation of natural grassland. Grassland biomass wouldn't change significantly in a short period of time. If the estimated period was short, the grassland utilization estimation could be based on the compensatory growth principle of the grassland.~~ According to the view that "the utilization process of natural grassland is a process of interaction between grazing behavior and vegetation growth", two factors of grassland vegetation growth and grazing behavior should be considered simultaneously when evaluating the utilization of natural grassland. To estimate the utilization of natural grassland in this study, the feed intake of the herd is calculated by using the trajectory data of the herd and the calculation model of feed intake, and the biomass of grassland is calculated by using the remote sensing data of natural grassland and the distribution model of grassland biomass. Then through the relationship between the feed intake and the biomass of grassland in a certain area, the utilization of grassland in this area is reflected.

In this study, the natural breakpoint classification method was used to classify the herd's feed intake and grassland biomass. Then, the utilization of grassland was estimated according to the compensatory growth principle of grassland. If the grassland biomass level was the same as the feed intake level, the grassland utilization was moderate utilization. If the grassland biomass level was less than the feed intake level, the grassland was over utilization. If the grassland biomass level was greater than the feed intake level, the grassland was light utilization~~(Eqn 3):~~ . The basic formula of grassland utilization y is as follows:

$$y = \begin{cases} B_T > I_T, \text{ light utilization} \\ B_T = I_T, \text{ moderate utilization} \\ B_T < I_T, \text{ over utilization} \end{cases} \tag{4}$$

~~Where A is the trajectory data, B is the remote sensing image data, T is the grazing cycle, I_T is the feed intake classification level, and B_T is the biomass classification level.~~ where T is the length of the estimation period. B_T is the classification level of the grassland biomass. I_T is the classification level of the herd's feed intake.

~~The function was achieved by calling the relevant functions, such as ExtractMultiValuesToPoints() function, AddField_management(), CalculateField_management() functions of ArcPy package and jenks_breaks() method of Jenkspy package.~~

F. Implementation of natural grassland utilization estimation system with sense of grazing environment

System Architecture

The architecture of the system was mainly divided into four layers (Fig. 1). They were application layer, presentation layer, business logic layer and data layer.

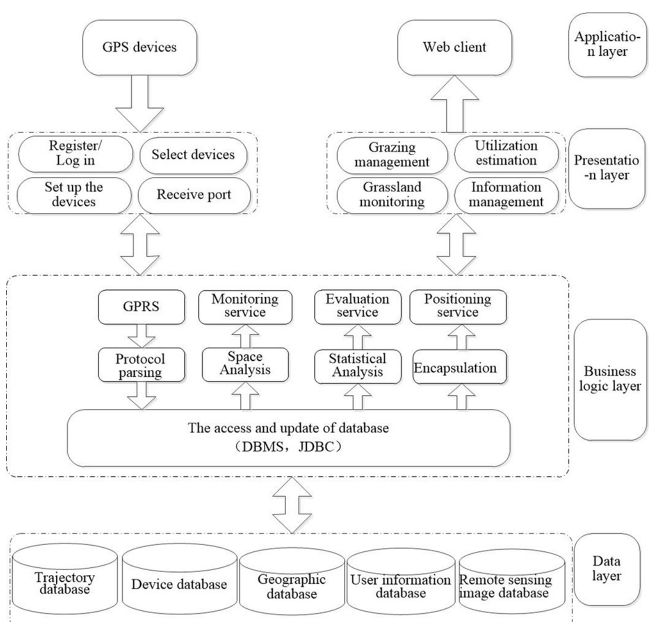

Fig. 1: System architecture diagram

The application layer consisted mainly of GPS devices and Web browsers (client). GPS devices were used to collect the trajectory data of herds. Web browsers were used to provide interface of data visualization to users.

In the presentation layer, we could select or add GPS devices, and set the communication mode, address and port of the GPS devices. According to different types of users, the system provided corresponding functions such as grazing management, grassland monitoring, grassland utilization estimation and information management.

In the business logic layer, GPS devices used GPRS technology to communicate with the GServer of the exlive platform. The GServer parsed the GPS protocol and stored the trajectory data into the database. The data was encapsulated into JSON format data to achieve the location service by calling the interface of GServer. Other functions of the business logic layer used the Python script to read the relevant data from the database and call the API of ArcGIS or ENVI to automatically process the relevant data at a fixed time. The results were published automatically to the ArcGIS Server. The thematic maps need a lot of historical GPS data, traditional servers need too much time to process large-scale data. Therefore, the spatial analysis server of this system was built on the cloud server by Hadoop, which improved the computing power of the traditional server, and the results were provided to users in time.

The data layer included a trajectory database, a device information database, a remote sensing image database, a geographic information database, and a user information database, which were respectively used to store GPS trajectory in-formation, GPS device information, remote sensing images, geographic infor-mation, and user information.

The achievement of Automatic Publishing Result Function

~~The results were automatically published to ArcGIS Server platform by Python script. The map documents in folders were automatically published to ArcGIS Server. Automatic publishing process is shown (Fig. 2)~~ The function of share the results as ArcGIS Server map service automatically is realized by writing Python script in the system. The specific steps of sharing are shown in Fig.4. The first step: Input the data of feature class such as feed intake, grassland biomass and herd trajectory. The second step: Add feature class data into layer, and then add layer into mxd document. The third step: Input GIS Server site URL, Server administrator account and password information. The fourth step: Determine whether there is a GIS Server service connection profile in the current folder. If not, create the GIS Server connection file directly according to the input information. Otherwise, delete the file and recreate it. The fifth step: Convert mxd document into service definition draft data (.sddraft). Sddraft file consists of map document, server information and a set of service attributes. The sixth step: Analysis sddraft file and detect the exception information. If there is no exception information, convert the sddraft file into a service definition file (. sd) and upload this sd file to the GIS Server. Otherwise, exceptions warning or error message will be thrown. The generated SD and sddraft files will be not deleted automatically. The seventh step: Output Shared status information. At this point, the automatic sharing of map elements is completed, and the access interface URL of the service is provided for the client.

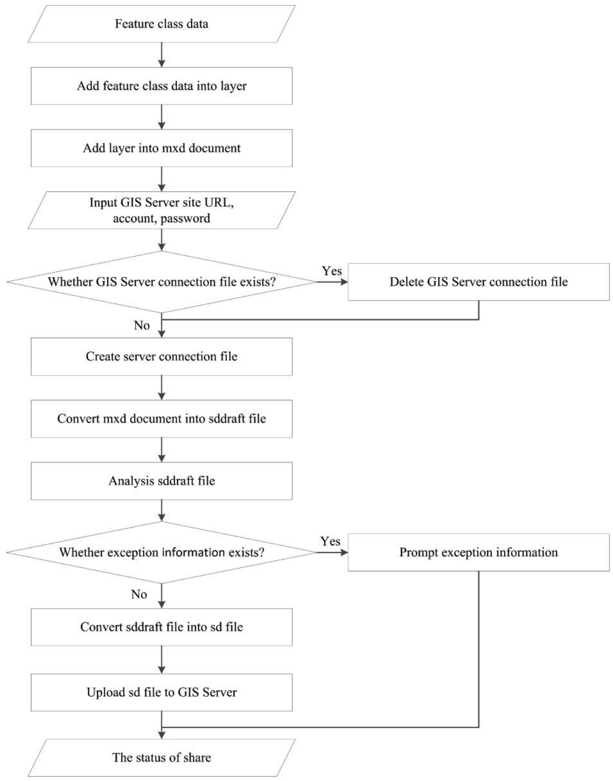

Fig. 2: Automatic publishing flowchart

III. Results

In this study, Ziniquan pasture, No. 151st regiment of the 8th division of Xinjiang production and Construction Corps was taken as an example. The experiment was carried out from April to August 2017. This experiment used the GT03C positioning devices produced by Shenzhen Gu Mi Electronics Co., Ltd. to obtain the real-time geographic location of the herd and upload it to the server. The uploaded data included device ID, latitude and longitude, transmission time, etc (Fig. 3).

id	VehicleID	UserID	gpstime	recvtime	lng	lat
11934	9331455	0	2017-06-01 09:51:51.000	2017-06-01 09:51:51.000	85.767564	43.997305
11935	9532020	0	2017-06-01 09:52:37.000	2017-06-01 09:52:37.000	85.7676	43.997406
11936	9339098	0	2017-06-01 09:52:45.000	2017-06-01 09:52:45.000	85.766982	43.997416
11937	9532021	0	2017-06-01 09:52:47.000	2017-06-01 09:52:47.000	85.767075	43.997368
11938	9339074	0	2017-06-01 09:52:53.000	2017-06-01 09:52:53.000	85.767113	43.997263
11939	9339085	0	2017-06-01 09:53:25.000	2017-06-01 09:53:25.000	85.767279	43.997299
11940	9339089	0	2017-06-01 09:54:05.000	2017-06-01 09:54:05.000	86.055775	44.309008
11941	9339077	0	2017-06-01 09:54:11.000	2017-06-01 09:54:11.000	85.766296	43.99791
11942	9339101	0	2017-06-01 09:54:12.000	2017-06-01 09:54:12.000	85.767113	43.997822
11943	9339078	0	2017-06-01 09:54:43.000	2017-06-01 09:54:43.000	85.766491	43.997897
11944	9331455	0	2017-06-01 09:54:51.000	2017-06-01 09:54:51.000	85.766528	43.997905
11945	9532020	0	2017-06-01 09:55:39.000	2017-06-01 09:55:39.000	85.76667	43.997948
11946	9532021	0	2017-06-01 09:55:43.000	2017-06-01 09:55:43.000	85.765746	43.998016
11947	9339098	0	2017-06-01 09:55:45.000	2017-06-01 09:55:45.000	85.765778	43.998048
11948	9339074	0	2017-06-01 09:55:52.000	2017-06-01 09:55:52.000	85.765701	43.998073
11949	9339085	0	2017-06-01 09:56:24.000	2017-06-01 09:56:24.000	85.766114	43.997833

Fig. 3: Data acquisition results

The spatial distributed map of the feed intake was obtained when the trajectory points as the input of the feed intake distribution model. The spatial distributed maps of grassland biomass were respectively obtained when satellite remote sensing image as the input of the grassland biomass models.

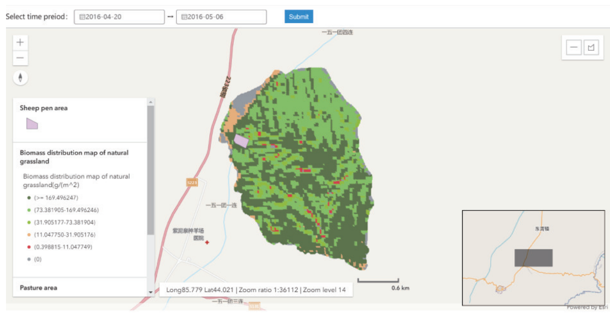

Fig. 4: Distribution of grassland biomass from April 20 to May 6, 2016

The natural grassland biomass was estimated from April 20, 2016 to May 6, 2016 by satellite remote sensing image (Fig. 4). The area of human activity was in the northwest part of the study. Other areas with high biomass were due to the exuberant growth of grass during this period. At the same time, the weather was so cold that the herd rarely fed in circles. Therefore, the growth speed of grassland was higher than the feeding speed of the herd. The less biomass in the study area was mainly due to the terrain was not suitable for grass to grow.

Grassland utilization in the study area was estimated by the estimation method of the study in July, 2016. The thematic map of the grassland utilization estimation was obtained (Fig. 5).

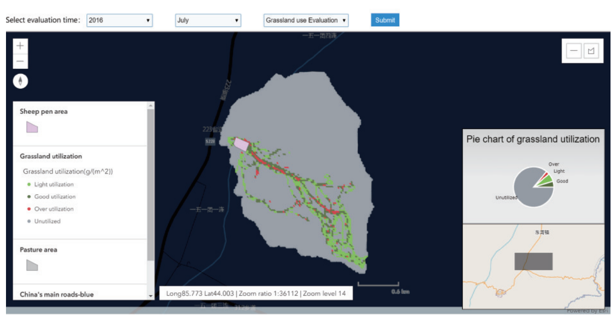

Fig. 5: Distribution of grassland utilization in July, 2016

It could be seen from Fig. 5 that the over utilization area was mainly distributed in near the road. The main reason for the over utilization was that the terrain of the area was flat, which was conducive to grazing and feeding of herds. And it was the area that herds often pass after they leave the sheepfold.

IV. Discussion and Conclusions

In this study, combining 3S technology, a grassland utilization evaluation method based on environmental perception is proposed, and a grassland utilization evaluation system was developed. Its main contributions and shortcomings were as follows:

The environmental perceive technology is a very effective tool in grassland utilization estimation. Considering that grassland utilization is a process of continuous interaction between herd grazing and vegetation growth, this study used GPS and satellite remote sensing to perceive the herd feeding and vegetation growth respectively. ~~It provided technical support for quantifying grassland utilization. Through classifica-tion and comparison of feed intake and biomass, the grassland utilization in each region was obtained. However, due to the limited precision of satellite remote sensing and the influence of weather, new tools will be introduced to monitor the grassland biomass in the next stage, so as to improve the precision and make the grassland biomass not limited by weather.~~ , and a grassland utilization estimation method based on environmental perception is proposed. According to the GPS trajectory data, the distribution of forage intake was obtained, and the biomass distribution of grassland was retrieved by using the satellite remote sensing estimation model of natural grassland. This technology gave full play to the advantages of GPS, and used the real-time characteristics of GPS to monitor the trajectory of herd, so as to calculate the feed intake of herd quickly. In the meantime, the cost of obtaining biomass information by satellite remote sensing is relatively low, so the biomass can be obtained in each remote sensing cycle, and the grassland utilization can be calculated. The method proposed in this study was tested with the Ziniquan pasture of Shihezi City, Xinjiang production and construction corps as an example. The method estimated the grassland utilization of the study area in July, 2016. The result showed that the over utilization area was mainly distributed in near the road. The main reason of over utilization was that the area is flat, which was conducive to the grazing of herd. The herd often passed the paths after they leave the sheepfold. However, the estimation effect of this method has certain requirements on the accuracy of satellite remote sensing. When the accuracy of satellite remote sensing is limited and affected by weather, the calculated value of grassland utilization is larger than the actual value. So in the next stage, new tools will be introduced to monitor the grass yield in the grassland, so as to improve the accuracy and make the grass yield not limited by the weather.

The study developed a grassland utilization estimation system. The system achieved the functions of distribution of feed intake, grassland growth monitoring and grassland utilization estimation. The web browser was used as the client of the system. The server was composed of GIS server, Web server, GServer and database. The system can deliver monitoring information to ranchers and animal husbandry management departments in time, so as to guide relevant people to adjust grazing area and promote the sustainable development of animal husbandry. However, the computing power of the system was often faced with the problem of insufficient system resources. The calculation of spatiotemporal data would consume a lot of system resources, and the relevant personnel may spend a long time waiting for the system response. Although the concept of space for time cloud be adopted, the evaluation of historical data would be calculated and stored in the form of files when the system was idle, but it also would bring new challenges to the storage capacity of the system.

Symbol	Definition
GPS	Global Positioning System
GIS	Geographic Information System
RS	Remote Sensing
SAVI	Soil Adjusted Vegetation Index
RVI	Ratio Vegetation Index
GPRS	General Packet Radio Service
JSON	JavaScript Object Notation
API	Application Programming Interface

List of Abbreviations

Availability of data and materials

The network behavior data used to support the findings of this study are available from the corresponding author upon request.

Competing interests

The authors declare that they have no competing interests.

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Author's contributions

CW formulated the research problem and contributed to the structuring, reviewing, and finalizing of the manuscript. . In a supervising role, DL and YT contributed to the discussion of results and gave some important suggestions for the development of the system. DL, YT, QW, TY, JW and WB completed the development of the system. All authors read and approved the final manuscript.

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Figure Title and Legend

Fig. 1: System architecture diagram. There are application layer, presentation layer, business logic layer and data layer in the architecture of the system.

Fig. 2: Automatic publishing flowchart. The results were automatically published to ArcGIS Server platform.

Fig. 3: Data acquisition results. The uploaded data included device ID, latitude and longitude, transmission time, etc.

Fig. 4: Distribution of grassland biomass from April 20 to May 6, 2016. The natural grassland biomass was estimated by satellite remote sensing image.

Fig. 5: Distribution of grassland utilization in 2016. The over utilization area was mainly distributed in the southwest of the study area.

Figures

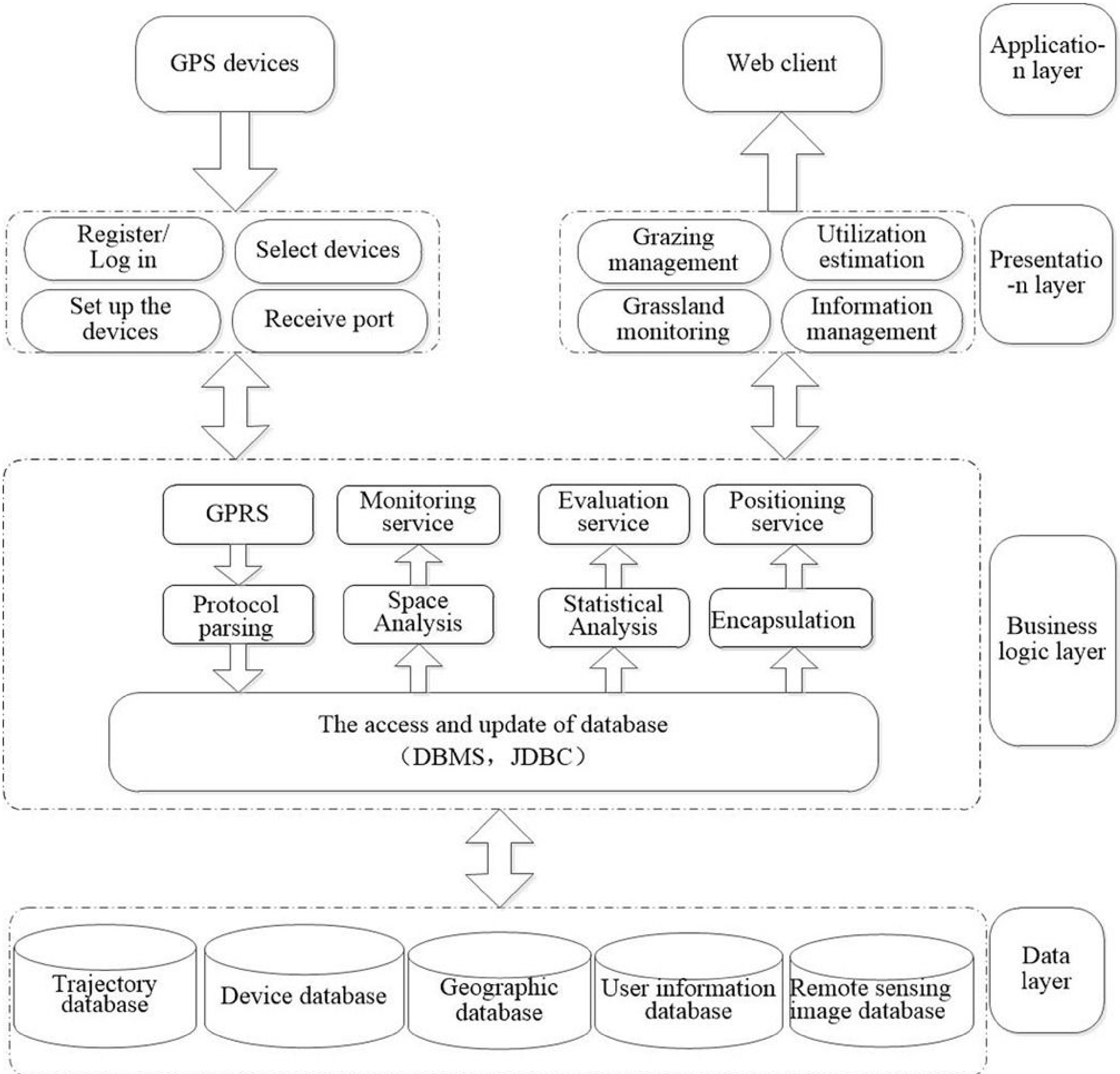

Figure 1

System architecture diagram. There are application layer, presentation layer, business logic layer and data layer in the architecture of the system

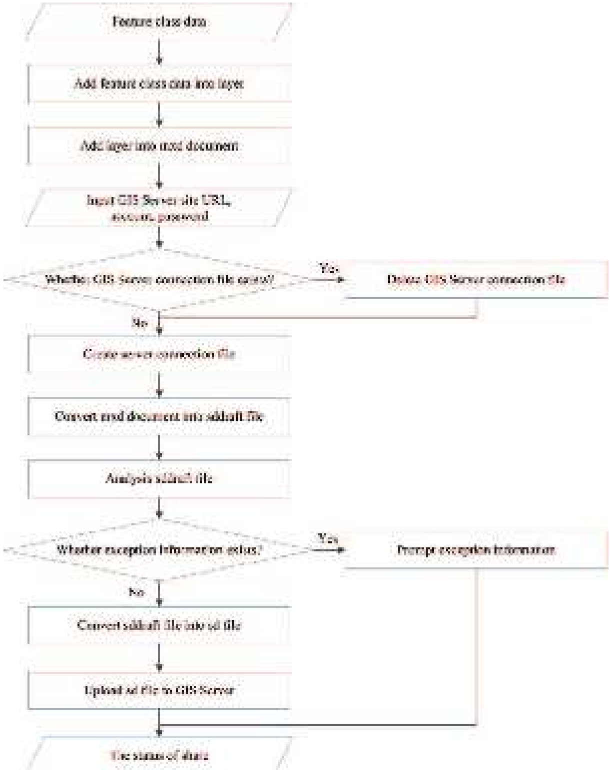

Figure 2

Automatic publishing flowchart

id	VehicleID	UserID	gpstime	recvtime	lng	lat
11934	9331455	0	2017-06-01 09:51:51.000	2017-06-01 09:51:51.000	85.767564	43.957305
11935	9532020	0	2017-06-01 09:52:37.000	2017-06-01 09:52:37.000	85.7676	43.957406
11936	9339098	0	2017-06-01 09:52:45.000	2017-06-01 09:52:45.000	85.766882	43.957416
11937	9532021	0	2017-06-01 09:52:47.000	2017-06-01 09:52:47.000	85.767075	43.957368
11938	9339074	0	2017-06-01 09:52:53.000	2017-06-01 09:52:53.000	85.767113	43.957263
11939	9339085	0	2017-06-01 09:53:25.000	2017-06-01 09:53:25.000	85.767279	43.957289
11940	9339089	0	2017-06-01 09:54:05.000	2017-06-01 09:54:05.000	86.055775	44.309008
11941	9339077	0	2017-06-01 09:54:11.000	2017-06-01 09:54:11.000	85.766296	43.95791
11942	9339101	0	2017-06-01 09:54:12.000	2017-06-01 09:54:12.000	85.767113	43.957822
11943	9339076	0	2017-06-01 09:54:43.000	2017-06-01 09:54:43.000	85.766491	43.957897
11944	9331455	0	2017-06-01 09:54:51.000	2017-06-01 09:54:51.000	85.766528	43.957905
11945	9532020	0	2017-06-01 09:55:39.000	2017-06-01 09:55:39.000	85.76667	43.957948
11946	9532021	0	2017-06-01 09:55:43.000	2017-06-01 09:55:43.000	85.765746	43.958016
11947	9339098	0	2017-06-01 09:55:45.000	2017-06-01 09:55:45.000	85.765778	43.958048
11948	9339074	0	2017-06-01 09:55:52.000	2017-06-01 09:55:52.000	85.765701	43.958073
11949	9339085	0	2017-06-01 09:56:24.000	2017-06-01 09:56:24.000	85.766114	43.957833

Figure 3

Data acquisition results

Figure 4

Distribution of grassland biomass from April 20 to May 6, 2016

Figure 5

Distribution of grassland utilization in July, 2016