Grazing Trajectory Statistics and Visualization Platform Based on Cloud GIS

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

[1] College of Information Science and Technology, Shihezi University, Shihezi 832000, China
wcj_inf@shzu.edu.cn

[2] Geospatial Information Engineering Research Center, Xinjiang Production and Construction Corps, Shihezi 832000, China

[3] Geospatial Information Engineering Laboratory, Xinjiang Production and Construction Corps, Shihezi 832000, China

Abstract. In order to meet the needs of ranchers and grassland livestock management departments for the visualization of grazing behavior, this study develops a statistical and visual platform for herd trajectory. The Web AppBuilder for ArcGIS and ArcGIS Online were used to implement statistics and visualization of herd trajectories. The walking speed, walking trajectory and feed intake of the herd were calculated by the GP service on the server. The calculation results were published to the ArcGIS online platform. The relevant information was analyzed and displayed by Web AppBuilder for ArcGIS calling the data on ArcGIS Online. This platform achieved the visualization function of walking speed, walking trajectory and feed intake of the herd. It can provide technical support and data support for relevant management departments to monitor grazing information and study the living habits of herds.

Keywords: ArcGIS · Trajectory · Statistics · Grazing

1 Introduction

Animal husbandry is an important part of agriculture. It has very important impact on socioeconomic development and people's production and life [1]. Grassland is an extremely important natural resource in the development of animal husbandry [2]. Rational use of grassland resources is related to the sustainable development of animal husbandry. However, most grassland has different degrees of grassland degradation [3], and overfeeding of herds on grassland is one of the causes of grassland degradation [4, 5]. In a period of time, the feed intake of the herd exceeds the tolerance limit of the grassland in the region [6]. It breaks the ecological balance of grassland and leads to the failure of regeneration of grassland resources. Therefore, it is necessary to analyze the grazing behavior of herds in time and accurately. It is of great significance to adjust grazing strategies, improve grassland productivity and protect grassland ecosystems [7, 8].

X. Zhang et al. (Eds.): CloudComp 2019/SmartGift 2019, LNICST 322, pp. 275–282, 2020.
https://doi.org/10.1007/978-3-030-48513-9_23

Traditionally, the feeding behavior was mainly studied by observation methods. Devices such as counters, stopwatches, and telescopes were used to track the feeding behavior of the herd [9–11]. But there are some limitations due to the number of people, devices capabilities and study area. The traditional methods waste time and energy. The information collected by traditional methods is small and the timeliness is poor. It is difficult to describe the spatiotemporal information of herd feeding behavior accurately [12].

In recent years, GPS (Global Positioning System) technology, GIS (Geographic Information System) technology, modern communication and computer technology have gradually matured. Domestic and foreign scholars have applied the above technologies into the grassland and animal husbandry [13, 14]. These methods are not limited by conditions such as time and terrain. It can record the grazing trajectory of the herd and generate spatiotemporal trajectory data containing the movement information of the herd. The habits of the herd can be studied through trajectory data [15, 16].

Arnon et al. conducted his experiment at a study site in the semi-arid region of the Negev, northern Israel. They used GPS devices to record the trajectory of the herd. They analyzed the herd's walking speed by the factors of the pasture (slope, aspect, and distance between the herd and the corral). The speed of flock movement is greatly affected by the distance of the corral. The flock walks fastest when the distance between the flock and the corral is the largest or the smallest. As the slope increases, the walking speed of the flock decreases. The walking speed of the flock is also affected by the aspect [17].

Henkin et al. studied the effects of topographical factors on cattle foraging behavior in hilly areas. In this study, they used the LOTEK 2200 series GPS collar (Lotek Engineering, Newmarket, ON, Canada) to record the trajectory of the herd at intervals of 5 min. They analyzed the grazing trajectory under different grazing intensities and different seasons. They found that the herd likes to eat in flat terrain. Only when the grazing intensity tends to be saturated or the forage biomass is low will it eat in areas with steep terrain [18].

Manuel Lomillos Pérez et al. used global positioning system and general packet radio technology (GPS-GPRS) to track and monitor free-range cow. The circadian rhythm map of the walking distance of cattle in a few hours was obtained. It was concluded that the average daily walking distance of cattle is 3.15 km [19].

Wang, Akasbi, Kawamura et al. used GPS devices to obtain temporal and spatial trajectory data of herd grazing. The feed intake distribution of herds was obtained by grid method [12, 20, 21].

According to the current literature, there are very few studies on the visualization platforms that provide ranchers and grassland livestock management departments with attribute information such as herd movement trajectory, walking speed, feed intake distribution and their relationship with grassland environment. The purpose of this study is to develop a statistical and visual platform for herd trajectory. The specific objectives are to 1) to calculate herd's walking speed, walking trajectories and feed intake, 2) to publish the results to ArcGIS Online, and 3) to show the relationship among trajectory points, grazing time and environment intuitively.

2 Data and Methods

2.1 Grazing Track Data Acquisition

In this study, the GT03C positioning tracker of Shenzhen Gumi was used to locate the geographical position of sheep. The positioning error of the device is less than 10 m. The overall quality of the device is 202 g. The specification is 91.5 mm × 57.0 mm × 37.5 mm (length × width × height). Hulbert et al. showed that when the ratio of the quality of the device and the quality of the sheep is less than 2.2%, it will not affect the physiological behavior and feeding speed of sheep [18]. In this experiment, the sampling time interval of GPS device was 3 min.

The trajectory data was collected from April to September 2016 and April to August 2017. During the sampling period, GPS data was uploaded to Exlive (Location Service Platform) and stored in Microsoft SQL Server 2008 database. The main information of trajectory data included GPS device ID, longitude and latitude information, sending time, etc. The trajectory data of this study were derived from the Ziniquan ranch, No. 151st regiment of the 8th division of Xinjiang production and Construction Corps. Its geographical location is 85°46′15. 06″ E, 44°00′13. 23″ N.

2.2 Grazing Track and Speed

Grazing Trajectory: T $= \{T_{1,1} \ldots, T_{i,j}, \ldots, T_{n,m}\}$ represents the trajectory unit set. It is a collection of herd trajectory over a period of time. $T_{i,j} = \{P_1, P_2, \ldots, P_n\}$ $(0 \le i \le n,\ 0 \le j \le m)$ represents the trajectory unit. It is the set of trajectory points of the j-th monitored sheep on the i-th day and the set of spatial points with time series. $P_{\mathrm{k}}(0 \le \mathrm{k} \le n)$ is the k-th trajectory point in the set of trajectory points, including longitude, latitude, positioning time t_i and other information.

Trajectory segment: Several trajectories $L_i\,(0 \le i \le n)$ were obtained by segmenting the trajectory elements. The segmentation method is based on the GPS points contained in the trajectory segment and GPS points are not less than 2. The smaller the number of trajectory points contained in the trajectory segment, the closer the fitted grazing trajectory is to the real grazing trajectory. Therefore, L_i represents the trajectory between two trajectory points P_i and P_{i+1}.

Grazing speed: The trajectory segment is a sequential trajectory segment connected by two trajectory points (Fig. 1). Therefore, grazing speed is the ratio of trajectory segment $\overrightarrow{P_\imath P_{\imath+1}}$ and the time difference $t_{i+1} - t_i$ (Eq. 1):

$$\overrightarrow{\mathrm{v_i}} = \frac{\overrightarrow{P_\imath P_{\imath+1}}}{t_{i+1} - t_i} \tag{1}$$

The study used the TrackIntervalsToLine_ta() function to calculate the trajectory speed and plot the trajectory of the herd. The trajectory of a sheep could be got by inputting device ID and using the MakeQueryTable_management() function.

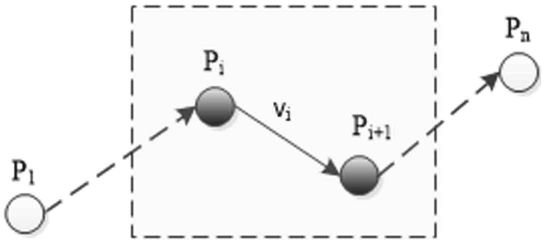

Fig. 1. The speed of grazing trajectory point in continuous time

2.3 Feed Intake Distribution

The feed intake distribution is a grid consisting of cells containing feed intake values and spatial information. Assuming that there is no significant difference between the total daily herd feed intake and daily herd speed of eating [12], the daily feed intake of the herd was calculated as:

$$D_{FID} = F(S, t_{start}, t_{end}, I_{DHFI}) = \sum\nolimits_{i=0}^{k} \sum\nolimits_{j=0}^{l} f\left(T_{i,j}, I_{DHFI}\right) \tag{2}$$

Where S is the given spatial region; t_{start}, t_{end} is the given start and end time. I_{DHFI} is the total daily feed intake. It is composed of the feed intake I_i of each trajectory segment. $T_{i,j}$ is the herd trajectory unit of the jth monitored sheep on the ith day. $f\left(T_{i,j}, I_{DHFI}\right)$ is the daily feed intake distribution generated by the corresponding trajectory unit $T_{i,j}$. The first summation is the distribution of feed intake for all herds in a day. The second summation is the distribution of feed intake for all herds over several days. The feed intake I_i was calculated as:

$$I_i = \frac{t_i \cdot v_{DHSE}}{S_i} = \frac{t_i}{S_i} \cdot \frac{I_{DHFI}}{t_{ADFT}} \ (0 < i < n) \tag{3}$$

Where t_i is the effective feeding time extracted from the time attribute of the trajectory segment L_i. v_{DHSE} is the average eating speed of the herd daily. S_i is the buffer area of each trajectory segment, and t_{ADFT} is the total daily feed time.

The study used the GenerateNearTable_analysis() function, the Buffer_analysis() function and the CalculateField_management() function to calculate the daily feed intake distribution of the herd. For the multi-day feed intake distribution of the herd, it was necessary to add up the daily feed intake of the herd.

3 Results

The architecture of the platform consisted of the presentation layer, the business logic Layer and the data layer (Fig. 2). The Web AppBuilder for ArcGIS framework was used by the Presentation Layer to provide a user-friendly display interface. It implemented some functions such as statistical analysis, spatial query, spatial analysis, map navigation operations and so on. The cloud computing-based GIS mapping platform (ArcGIS Online) was used by the business logic layer to create a basic map service. The platform built some models for calculating speed, trajectory and feed intake through ArcGIS. The models were packed as GP services. They were uploaded to the server for trajectory data processing. The Data Layer provided the system with the data of pasture boundary and trajectory points of herd.

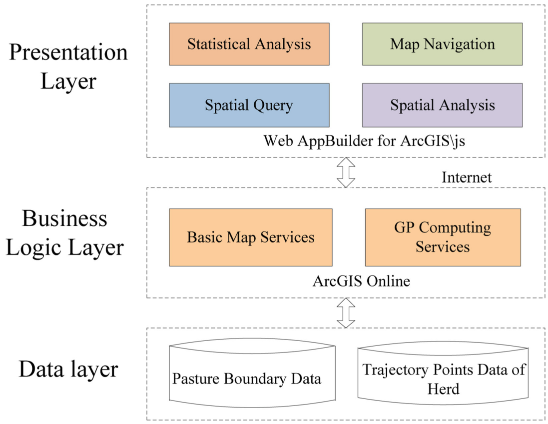

Fig. 2. Platform architecture diagram

The platform could calculate the speed, altitude and slope of the trajectory points of the herd. It also could display information such as the herd trajectory and the proportion of the number of trajectory collected by various devices. Meanwhile, the relationship between walking speed and grazing time could be analyzed.

In this study, Ziniquan pasture, No. 151st regiment of the 8th division of Xinjiang production and Construction Corps was taken as an example. The trajectory relation diagram of the herd was obtained by collecting the trajectory information of the herd on June 16, 2017 (Fig. 3). Figure 3 shows that there were 5 GPS devices to monitor the grazing behavior of the herd on that day. The number of effective trajectory points recorded was 745. The herd was about to leave the sheepfold for feed at 6:40 a.m.

The trajectory route and the feed intake of sheep with sheepID 9339081 on June 23, 2017 was calculated (Fig. 4). From the heat map of feed intake, it could be seen that the feeding area of this sheep is in the east and southeast of the pasture. According to the chart of feed intake changing with grazing time, we can know that the sheep left the sheepfold at about 8:00 a.m. The sheep arrived at the feeding area around 8:30 and began to eat freely. This sheep walked basically in the valley. This hills and slopes may be steep, which was not conducive to feed for sheep. The terrain of the valley area may be flat. The feeding along the valley may be consistent with the feeding and grazing habits of sheep.

Fig. 3. Trajectory graph of the herd on June 16, 2017

Fig. 4. Feed intake graph of sheepID 9339081 on June 23, 2017

4 Discussion

The platform achieved the visual display of the walking speed, the walking trajectory, the feed intake and other data of the herd. It was developed by Web AppBuilder for ArcGIS framework. The platform uses the ArcGIS model builder to build models. The models were published as GP service to calculate walking speed, walking trajectory, feed intake of herd and other attribute information on the server. The GIS mapping platform (ArcGIS online server) was used to publish map services. It is beneficial to make a reasonable grazing strategy and promote the sustainable development of animal husbandry. However, the grazing behavior of the herd can't be monitored in real time. For example, the walking speed and direction of the herd can't be measured in real time. In addition, the platform mainly relies on ArcGIS online platform so that the display of results is slightly delayed. Therefore, we will add the functions of grazing trajectory prediction, real-time monitoring of walking speed, and improve the loading speed of data in the future study.

5 Conclusions

The trajectory statistics and visualization platform based on cloud GIS achieved the visual display of the walking speed, the walking trajectory and the feed intake of the herd. It also could show the relationship among trajectory points, grazing time and environment intuitively. It can make ranchers, grassland livestock management departments and related researchers intuitively understand the feed state and habits of the herd.

Acknowledgments. We highly appreciate the Yang Yonglin of the Xinjiang Academy of Agricultural Reclamation and the pastoralists of Ziniquan farm, who participated in the GPS trajectory data collection and shared their knowledge on herd. We are thankful to all the professional GIS technicians, graduate students and undergraduates who contributed to the development of this system. We are grateful for the thoughtful and constructive comments of the reviewers that improved this manuscript in major ways.

Funding. This work was supported by the National Key R&D Program of China (Grant No. 2017YFB0504203), the National Natural Science Foundation of China (Grant No. 41461088, and the XJCC XPCC Innovation Team of Geospatial Information Technology (Grant No. 2016AB001).

Conflicts of Interest. The authors declare no conflict of interest.

References

1. Zhao, Q., Hou, X., Duan, J., et al.: Production benefit trend analysis of grazing regime by sunite wether on mixed artificial pasture. Chin. J. Grassl. **41**(3), 130–135 (2019)
2. Voormansik, K.: Observations of cutting practices in agricultural grasslands using polarimetric SAR. IEEE J. Sel. Top. Appl. Earth Obs. Remote Sens. **9**(4), 1382–1396 (2016)
3. Chen, Y.X., Lee, G., Lee, P., et al.: Model analysis of grazing effect on above-ground biomass and above-ground net primary production of a Mongolian grassland ecosystem. J. Hydrol. **333**(1), 155–164 (2007)
4. Marquart, A., Eldridge, D.J., Travers, S.K., et al.: Large shrubs partly compensate negative effects of grazing on hydrological function in a semi-arid Savanna. Basic Appl. Ecol. **38**, 58–68 (2019)
5. Yu, L., Chen, Y., Sun, W., et al.: Effects of grazing exclusion on soil carbon dynamics in alpine grasslands of the Tibetan Plateau. Geoderma **353**, 133–143 (2019)
6. Shen, H., Zhu, Y., Zhao, X., et al.: Analysis on the current situation of grassland resources in China. Sci. Bull. **61**(02), 139–154 (2016)
7. Liu, J., Wang, Z., Hao, D., et al.: Effect of heavy grazing on the organization ability of main plant species and functional groups in a desert steppe. Chin. J. Grassl. **40**(5), 85–92 (2018)
8. Yin, G., Qian, H., Wei, Z., et al.: Comparison of grazing sheep foraging behavior at different environment. Acta Agric. Bor. Sin. **24**(4), 205–208 (2009)
9. Guo, Q., Yin, G., Zhao, H., et al.: Study on grazing behavior and feed intake of grazing sheep. J. Chin. Acad. Grassl. **33**(4), 95–98 (2011)

10. Wang, S., Li, Y.: A study on behavior ecology of grazing sheep III influence of grazing time on grazing behavior. Acta Prataculturae Sin. **06**(02), 7–13 (1997)
11. Wang, H., Ding, X., Lang, X., et al.: Foraging behavior of Oula sheep in summer pastures of Maqu Gannan. Acta Agrestia Sin. **20**(03), 583–588 (2012)
12. Wang, C., Wang, W., Lu, W., et al.: Distribution model of herd feed intake based on grazing time-space trajectory data. Trans. Chin. Society Agr. Eng. **32**(13), 125–130 (2016)
13. Benke, K.K., Sheth, F., Betteridge, K., et al.: Application of geovisual analytics to modelling the movements of ruminants in the rural landscape using satellite tracking data. Int. J. Digit Earth **8**(7), 579–593 (2015)
14. Wu, Q., Yang, B.: 3S-based grassland information system for Western China. Trans. Chin. Soc. Agr. Eng. **17**(5), 142–145 (2001)
15. Du, Y., He, P., Li, B., et al.: Research on regional attribute mining based on herd trajectory in massive pastoral areas. Appl. Res. Comput. **35**(04), 1033–1036 (2018)
16. Wang, X.: The effects of different grazing management system on livestock behavior. Inner Mongolia University (2017)
17. Arnon, A., Svoray, T., Ungar, E.D.: The spatial dimension of pastoral herding: a case study from the Northern Negev. Isr. J. Ecol. Evol. **57**(1–2), 129–149 (2011)
18. Henkin, Z., Ungar, E.D., Dolev, A.: Foraging behaviour of beef cattle in the hilly terrain of a Mediterranean grassland. Rangeland J. **34**(2), 163 (2012)
19. Pérez, J., Varga, M., García, J., et al.: Monitoring lidia cattle with GPS-GPRS technology: a study on grazing behaviour and spatial distribution. Vet. Mex. **4**(4), 1–17 (2017)
20. Akasbi, Z., Oldeland, J., Dengler, J., Finckh, M.: Social and ecological constraints on decision making by transhumant pastoralists: a case study from the Moroccan Atlas Mountains. J. Mt. Sci. **9**(3), 307–321 (2012). https://doi.org/10.1007/s11629-009-2320-8
21. Kawamura, K., Akiyama, T., Yokota, H.O., et al.: Quantifying grazing intensities using geographic information systems and satellite remote sensing in the Xilingol steppe region, Inner Mongolia, China. Agr. Ecosyst. Environ. **107**(1), 83–93 (2005)