ALGORITHMS FOR CALCULATING ACTUAL WORKED SURFACES IN AGRICULTURE

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Abstract

The need to accurately determine the surface of an agriculture field has been a common problem for a long time. The initial solution for this was a manual measuring system. However, this solution is time-consuming and can also generate inaccurate results. Since the popularisation of IoT devices and GPS tracking systems, it has become easier and faster to develop automatic solutions in order to precisely calculate the work area of an agriculture field. This article studies multiple ways to compute the field surface area based on agriculture machinery data in order to easily track and manage machinery usage and efficiency. The focus of this paper is the work area detection and surface calculation of the system using different techniques based on not only latitude and longitude correlations but also the altitude factor that can heavily influence the real surface of a field.

Key words: surface estimation, GPS, agriculture machinery tracking

Since the industrialisation of agriculture, it has become harder and harder to accurately manage the actual work volume of machinery for a farm because of the sheer work quantity but also due to irregularly shaped areas and the multitude of machinery manipulation approaches. The development of IoT and tracking devices for agriculture machinery has revealed the opportunity to create a software industry that can capitalise on the extensive amount of data and can automate the tracking and management of machinery even for large-scale farms.

This subject of automatic surface determination (Muhammad W. *et al*, 2020) has been explored, but we identified some weaknesses that still need to be addressed in the existing algorithms in the hope of achieving a more accurate result.

There are several methods that can be used to calculate the actual worked surfaces in agriculture. Here are a few:

This method involves dividing the field into a grid of equal size and then counting the number of grid squares that have been worked on. The total number of squares multiplied by the size of each square will give the actual worked surface.

This method involves using GPS technology to track the movement of farming equipment across the field.

This method involves using aerial or satellite imagery to detect changes in vegetation or soil in order to detect areas that have been worked by agricultural machinery.

This method involves mounting sensors on the farming equipment in order to track their movement and other engine related data.

This method involves mapping the yield of the crop as it is harvested. By comparing the yield map to the expected yield, it is possible to identify the areas that have been worked.

MATERIAL AND METHOD

Our approach relies on sensors mounted on tractors, which capture instantaneous GPS coordinates and the velocity of agricultural machinery. The objective of this study was to devise an algorithm that could discern cultivated field areas by utilising only these two data points, thereby enabling the development of an analytical and tracking tool for farm management teams.

Test data was collected by logging daily sensor data from tractors over an extended period and supplementing it with area measurements obtained from manual methods or, when possible, the area values recorded in the Romanian national registry.

Taking into account our available data, we can see that it is a common solution (Dyer C., 2013)

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to use a convex hull algorithm(Bernard C., 1993) and a concave hull algorithm (Adriano M., Maribel S., 2007) to determine the outline of a work surface and to compute its area using triangulation. However, there are a few requirements that the mentioned work did not address by only taking into account the latitude and longitude coordinates. The working area is not completely flat, and we are actually dealing with area computation for a surface mesh; for fields that are situated on a hill, for example, the real surface is larger if the altitude is taken into account.

The developed algorithm has a preprocessing step that removes turns based on work angle, vehicle speed and work points density. We also explored different types of area calculation in order to compare the results for multiple types of regular and irregularly shaped fields. For outline determination, we explored both convex hull and concave hull, together with Delaunay Triangulation on the resulting outline in order to compute the area. We also explored an alternative method of area computation using the detected work lines and the vehicle width. The accuracy of these methods on different types of fields can be seen in the results section.

RESULTS AND DISCUSSIONS

The first approach was to use the Convex Hull algorithm together with Delaunay Triangulation in order to define an outline of the points and compute the area. In the area calculation process, the altitude was also considered. The distance between triangle points was considered a 3D distance between latitude, longitude and altitude coordinates. First, we compute the great-circle distance between the points, and then we combine it with the delta in altitude. The final triangle area is computed with Heron's formula.

The second approach included using a Concave Hull algorithm described in order to correctly identify the shape of the field. For fields with irregular shapes, the Convex hull algorithm does not work because connecting points of extremes can add to the outline additional sections that significantly increase the computed area.

The second approach was to go along the work line and multiply the entire travelled route with the vehicle width, using the distance formula described previously. This method is simple and accurate enough when the lines worked by the vehicle are correctly identified, and the vehicle width is known.

For all types of fields, taking into account both the cases when the work separation was correctly identified and not, the Convex Hull algorithm has an average error of 41.50%. The Concave Hull algorithm had a small improvement with an average error of 41.40%. This is because it is not possible to define a concavity parameter that works for all types of shapes. These two algorithms proved to yield unsatisfactory results even when the separation of points was good as can be seen in the figures below.

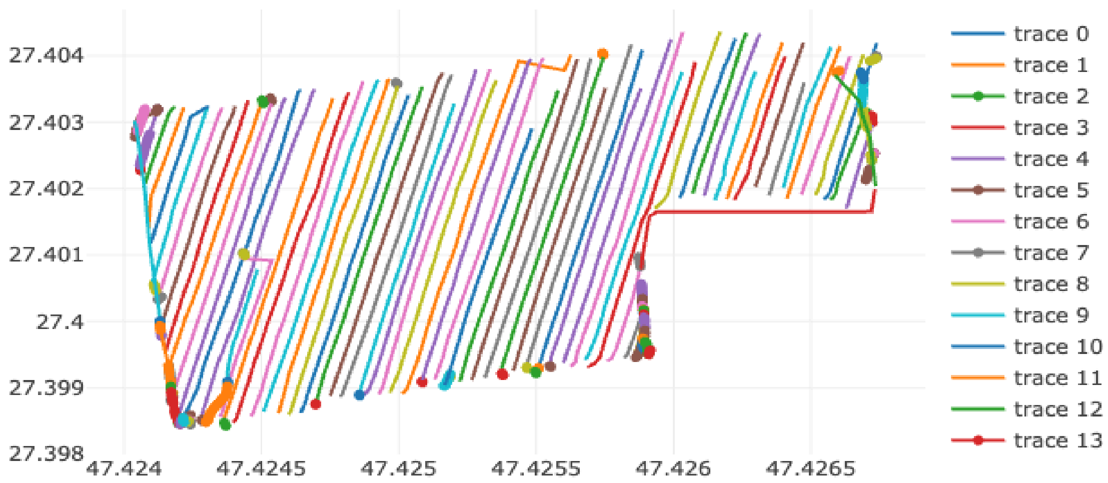

Figure 1 **Field shape after points separation**

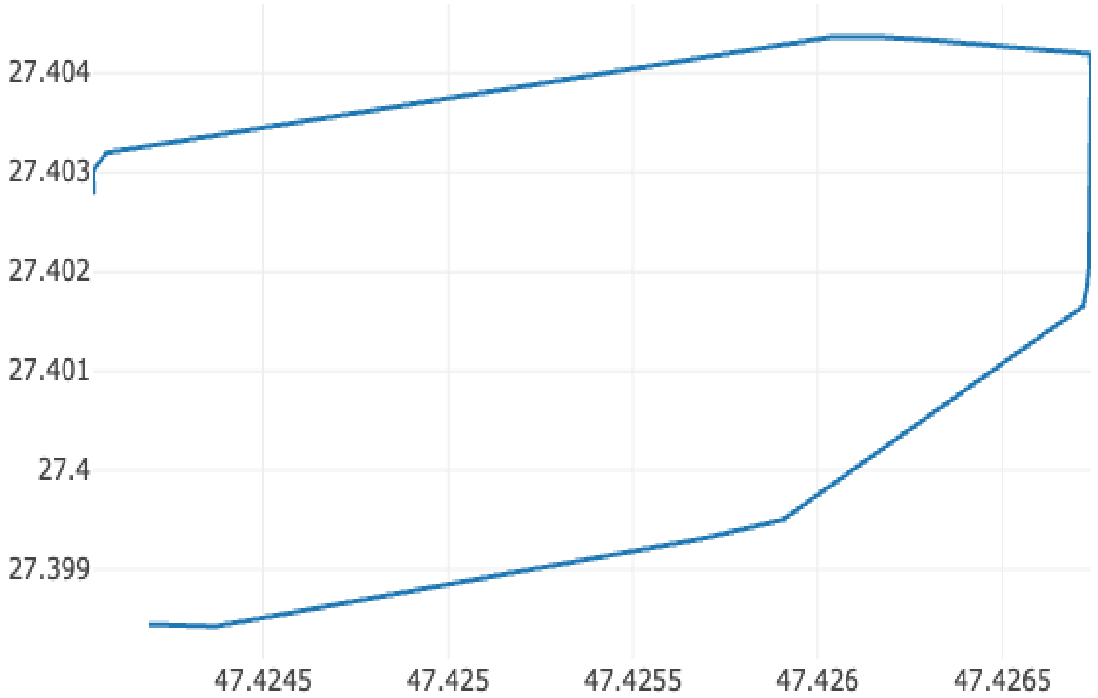

Figure 2 **Computed outline for points in Fig. 1**

The identified outline added a section to the work area that increased the error, reaching 37%, while the most simple approach, multiplying the worked distance with the vehicle width, would stay in the range of a 1% or 3% for a correctly made separation.

CONCLUSIONS

The best method proved to be the multiplication of distance with the vehicle width, and these results lead to future work into solving problems that add to this method's computational error. The first direction is detecting overlapping vehicle movements and removing them, but also detecting movements that are further than vehicle width. To further improve this method, a direction is automatically detecting the vehicle width based solely on the movements without any need for external input.

Nevertheless, this technique is heavily reliant on the separation performed in the preprocessing stage, which may be imprecise due to the contour of the field and the direction of cultivation. As a result, the accuracy of the convex hull area calculation was found to be superior to that of this approach. This is why a future direction of improvement would be to automatically detect the types of fields in which the separation step could yield inaccuracies and apply either of the two area calculation algorithms accordingly.

All in all, the outcomes of the investigation substantiate that monitoring GPS and velocity coordinates of agricultural machinery can be employed to accurately determine the actual area of fields while considering the altitude and slope factors. The usages of this algorithm can be extremely varied:

Calculating the actually worked surface area is crucial for estimating crop yields accurately. If the actually worked surface area is not measured, the yield estimates will be inaccurate, which can lead to over or underproduction and economic losses.

Calculating actual worked surfaces can help farmers to better manage their resources, including labour, water, fertilisers and fuel. This can lead to more efficient use of these resources, reducing costs and environmental impact.

Many countries have regulations in place that require farmers to accurately report their actual worked surface areas.

Knowing the actually worked surface area can help farmers to make informed decisions about crop rotations and planting density.

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