REAL-TIME FUEL CONSUMPTION MONITORING ALGORITHMS FOR ACCURATE FUEL CONSUMPTION DETERMINATION

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Abstract

For a long time, accurately determining the fuel consumption of agricultural machinery for worked fields has been a common issue. Initially, a manual measuring system was used to measure the amount of fuel left in the tank after a day of work. However, this solution is both time-consuming and prone to generating inaccurate results when multiple fuel refills are required in a day and multiple fields are worked. With the advent of IoT devices and GPS tracking systems, developing automatic solutions to precisely calculate this metric has become faster and more feasible. This article delves into ways of computing fuel consumption for agricultural machinery, enabling easy tracking and management of machinery usage and efficiency.

Key words: fuel consumption estimation, GPS, agriculture machinery tracking

Tracking and management of farm machinery have become increasingly difficult since the industrialisation of agriculture. The irregular shapes of fields, diverse machinery manipulation methods, and the vast amount of work all contribute to this challenge. However, the emergence of IoT technology and tracking devices for agriculture machinery provides an opportunity to create a software industry that can automate the tracking and management of machinery. This industry can leverage the copious amounts of data available, even on large-scale farms.

The main objective of this article is to determine the fuel consumption of agricultural machinery. To achieve this, a preprocessing algorithm is utilised to identify the actual work areas and the transit points, providing a more comprehensive view of the fuel consumption data. Both constant and non-constant fuel rate functions are considered, and the results are compared.

The study of fuel consumption in agricultural machinery is an ongoing and active research area with many recent advancements and developments.

Suchul K. *et al*. used OECD tractor test data to develop a method for predicting the fuel consumption of agricultural tractors under any operational conditions (Suchul K. *et al*, 2014). The method is based on the assumption that fuel consumption at varying loads with the full throttle is linearly proportional to power, and the difference in fuel consumption at varying loads with full and reduced throttles is equal regardless of engine power level if their speed difference is the same. The results showed that the predicted fuel consumption for the selected four tractor models ranged from 0.11% to 9.15% depending on speed and throttle, demonstrating that fuel consumption may be estimated reasonably well using only speed and fuel rate data. This discovery was a starting point for our experiments.

Another approach was presented by T. Jokiniemi in 2012, where fuel level sensors were developed and attached to each type of machinery to compute an average consumption metric useful for determining work efficiency (Jokiniemi T *et al*, 2012). Using these sensors, the error was 10% as the focus was not on efficiency but on extracting information about average conditions.

The article "Real-Time Fuel Consumption Monitoring System Based on Big Data Analysis", published in the Journal of Energy Engineering in 2021, proposed a real-time fuel consumption monitoring system that utilises big data analysis techniques to provide accurate fuel consumption information. The proposed system collects data from various sensors such as the fuel flow sensor, vehicle speed sensor, engine speed sensor, and GPS sensor. The data collected is processed in real-time using an algorithm that estimates the fuel consumption rate. The fuel consumption model is developed using a large dataset of real-world fuel consumption data. The dataset is preprocessed to

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remove outliers and missing data and then used to train the machine learning algorithms such as artificial neural networks and decision trees. The developed system was tested on a heavy-duty truck, and the results showed that it could accurately determine the fuel consumption rate with an error rate of less than 2%.

Although the proposed solutions, including fuel level sensors, have proved to be efficient, for our purpose, this approach is not applicable due to the long measuring time needed for extracting these metrics and the changing conditions in the type of work, terrain, and attachments. This is why we focused solely on GPS information and mathematics but also considered the usage of more complex models in future work.

MATERIAL AND METHOD

In modern agricultural practices, the use of autonomous vehicles equipped with various sensors and global positioning systems has become increasingly common. However, the amount of data generated by these vehicles can be overwhelming and often contains irrelevant information that needs to be filtered out. To address this challenge, a preprocessing algorithm is utilised, which employs advanced techniques to extract meaningful information from the raw data. Specifically, this algorithm analyses critical parameters such as the movement angle, vehicle speed, and point density to identify the actual work points, thereby removing unwanted data such as turns, obstacles, and sections of travel between fields.

By processing the data in this manner and separating it, as shown in Figures 1 and 2, it is possible to determine precisely how much fuel was used while working a field or while moving between fields. This information can provide valuable insights for the vehicle management team, allowing them to make data-driven decisions regarding fuel consumption and efficiency. For instance, by identifying the optimal route to travel between fields and the most efficient way to perform the necessary work, the vehicle management team can reduce fuel consumption, minimise wear and tear on the vehicles, and, ultimately, save on operational costs.

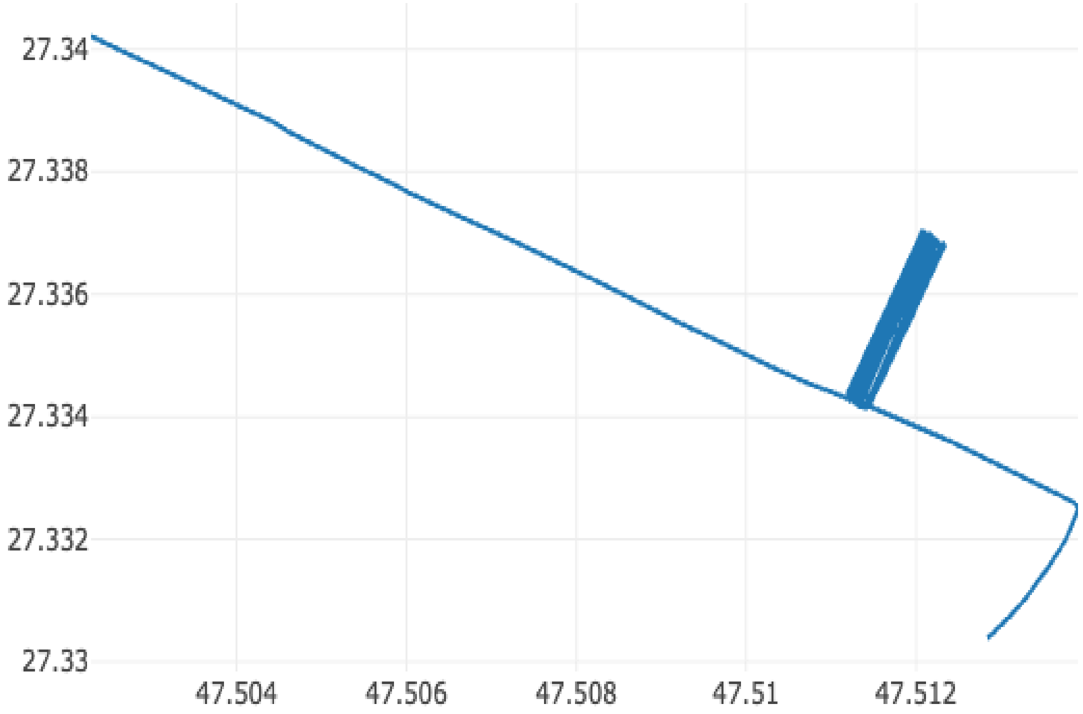

Figura 1 **Data points for the entire route**

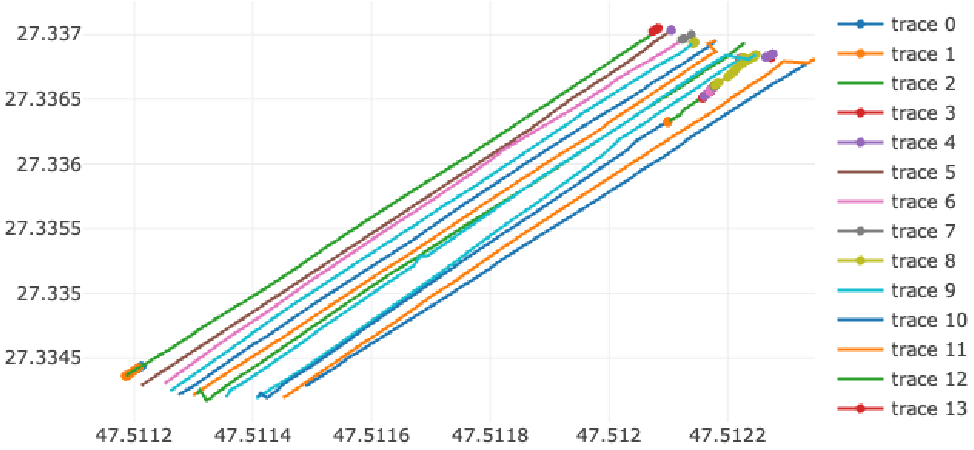

Figura 2. **Separation of work lines**

To estimate fuel consumption, two different approaches were employed in this study. The first approach utilised a formula for constant fuel rate, which estimates fuel consumption based on the distance travelled, measured in kilometres, and the fuel rate, measured in litres per kilometre. Specifically, this equation is represented as Distance * Fuel Rate, as shown below:

*Consumption = Distance * Fuel Rate (in Liters)*

It is essential to note that this formula provides an approximation of fuel consumption and may not account for all factors that can influence fuel consumption, such as terrain, weather conditions, and operator behaviour. Moreover, this formula assumes a constant fuel rate, which may not hold true in all operating conditions.

To overcome the limitations of the previous approach and improve the accuracy of fuel consumption estimation, the second approach considered fuel consumption as a non-constant function. Specifically, fuel consumption was estimated as the integral of the product of fuel rate and velocity over time, as shown below:

$$Fuel\ Consumption\ =\ \int (FR(t)\ *\ V(t))\,dt$$

In practical applications, the velocity, V(t), can be determined using the GPS coordinates and timestamps between two consecutive data points. Specifically, it is computed as the change in position divided by the change in time, i.e., $(change\ in\ position)\ /\ (change\ in\ time)$.

In order to evaluate the effectiveness of the fuel consumption algorithm; it is necessary to compare its estimates with actual fuel consumption data. Obtaining real consumption data for only the worked field section, without taking into account turns and obstacles, would be impractical and would require extensive resources, time, and effort. In addition, the evaluation of the consumption algorithm would be heavily dependent on the accuracy and effectiveness of the separation algorithm employed.

To address this challenge, the consumption algorithm was evaluated against consumption data for larger periods of time, such as a full day of work or refilling the tank before and after working a field, to see how much fuel was consumed in the field section. This approach allowed for a comprehensive evaluation of the consumption algorithm's accuracy and reliability, as it takes into account the entire range of operating conditions, including moving between fields and working in the fields.

RESULTS AND DISCUSSIONS

For the constant fuel rate formula, the average error was 1.66%, calculated for the whole field information, including turns and going-around obstacles. For the whole workday consumption, the error was 7.04%.

The second method of computation had an average error of 19.86%, computed from separate field information. However, this method was better at averaging fuel consumption over a larger dataset, resulting in a smaller error of 3.6% for the whole workday consumption. Nevertheless, it is worth noting that this method may indicate issues with the algorithm's evaluation data, which could impact the accuracy of the results.

These results highlighted that the real field consumption data is prone to inaccuracies because of the challenge of perfectly matching the data points between the points of fuel refill and efficiently communicating with the machinery personnel. This is why we heavily relied more on the whole workday results in assessing the algorithm accuracy but also took into account that the constant formula is better at measuring consumption for shorter periods of time with the intention of further investigating this assumption with future test data.

CONCLUSIONS

The analysis of the fuel consumption prediction algorithms revealed two potential avenues for improving accuracy. One possible approach is to integrate both fuel consumption formulas to achieve greater precision. This would involve utilising a constant fuel rate consumption formula for shorter periods, such as individual fieldwork, and an integral function for larger periods, like a full workday.

Another potential direction for improvement is to collect more reliable evaluation data, which could include closely monitoring the tank refilling process after each worked portion or implementing a fuel level measuring system, as suggested in [2]. Such additional measures would facilitate better management, tracking, and data collection, as well as insights into fuel usage patterns.

Despite the potential for improvement, the results of the analysis were satisfactory and demonstrated that using only fuel rate and velocity data from agricultural machinery can yield a reliable estimate of fuel consumption.

ACKNOWLEDGMENTS

This research is co-financed by the European Fund for Regional Development through the Competitiveness Operational Program 2014 – 2020, project “Establishment and implementation of partnerships for the transfer of knowledge between the Iasi Research Institute for Agriculture and Environment and the agricultural business environment”, acronym “AGRIECOTEC”, SMIS code 119611.

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