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DETERMINATION OF HOPPER FULLNESS OF SMART SCREW PRESS USING MACHINE LEARNING

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Abstract. Problem statement. This research addresses the challenge of accurately determining the fullness of the hopper within a screw press for optimal oil extraction efficiency and quality. Existing weight or volume-based measurement methods can often struggle with determining the feed hopper fullness due to variable oil weights during extraction stages, material heterogeneity, environmental influences and imprecise instrument calibration. Purpose. The study proposes a novel solution via the application of machine learning, specifically aiming to develop and validate a technique that uses acoustic signals to calculate screw press bowl load. Methodology. To implement this solution, the study uses quantitative research, data collection and data analysis, supervised learning. The method is based on the processing of audio data received from microphones located near the auger and the use of machine learning algorithms, such as sound classification. Model training process was facilitated by ML tool Arduino. Findings. The results of this study, facilitated by effective data analysis via ML tools, demonstrate that the evaluated filling level of the screw press hopper can effectively be determined by the sound signals produced and corresponding machine learning algorithms. Originality. The distinct advantage of this approach lies in its ability to automate the monitoring and operational control process of the oil press, thereby improving device efficiency and resource conservation. Practical value. The proposed approach allows to automate the process of determining the fullness of the bowl and monitor the condition of the auger by its sound characteristics. This solution can be utilized in the oil production industry to enhance the productivity of the screw presses. This research underscores the promise of machine learning applications and the potential for future research focusing on improving model adaptability and developing predictive maintenance systems. These future investigative scopes could essentially revolutionize monitoring and operational practices within the oil extraction industry.

Keywords: Arduino, oil pressing, automation, smart technology, sound, machine learning.

Introduction

Screw presses (fig. 1), which are used to extract oil from various raw materials, have long attracted the attention of scientists and engineers due to their importance and potential in agriculture and industry [1]. Various aspects of their functioning, including technological aspects, process optimization, and equipment improvement, are widely discussed in the global scientific literature. Sunflowers are primarily cultivated for food purposes [2]. For example, the central region of Italy is the most important area for sunflower production, with a seed production of over 150,000 tons and a cultivated area of 72,600 hectares. However, the demand for sunflower oil exceeds the production capacity, leading to a significant amount of imported sunflower oil in Italy. This has resulted in an increase in the production of cold-pressed sunflower oil, particularly by small-scale operators such as farmers who have become oil producers.

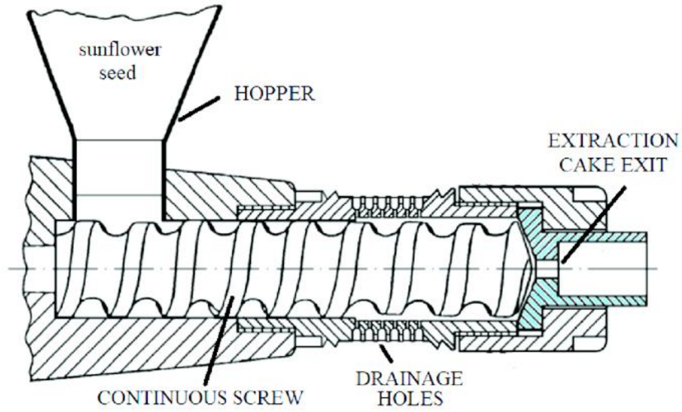

Fig. 1. Oil screw press [2]

There are several factors each oil producer should consider, as these factors can strongly influence the screw press's performance and productivity. Different materials have varied oil content and consistency; hence, the type of seed or material can significantly affect the screw press's productivity. Factors like temperature, humidity, and pressure can change the properties of the oil or the material to be pressed. Then, the configuration of the screw press, including the press's speed and the clearance between the cage bars, can also impact its performance. Fullness of seed hopper: if the seed hopper becomes too full, it could lead to jamming or overloading of the screw press, thus hampering its productivity. Conversely, if it is under-filled, the press could be underutilized, leading to lower productivity levels.

It is vital to monitor and control each of these aspects to optimize the performance and productivity of a screw press effectively. While numerous studies analyse factors such as the quality of material, environmental conditions, equipment setup, and working conditions of the screw press, the fullness of the seed hopper has not received substantial attention.

Currently, the fullness of the screw hopper is often determined by quantifying the weight or volume of oil squeezed out. Given this information, production operators can infer how full the hopper is based on the amount of oil produced, considering the known oil content of the specific material being pressed. This method, however, can present problems of accuracy due to variances in the weight of oil at different extraction stages, potential oil loss within the system, and environmental factors that can change the properties of the oil or material being pressed. The load of the press and the power consumed by the screw press can also provide an indirect measure of the hopper's fullness level. Some systems may have limited accuracy or measurement capabilities that limit their effectiveness in determining the fullness of the oil extraction cup. The solution to these problems may include the improvement of measurement systems, the use of more accurate devices, as well as the improvement of technologies for squeezing and processing the seeds material.

Object of research – application of machine learning for determination of hopper fullness of smart screw press.

Subject of research – the evaluation of the filling level of the screw press hopper using acoustic signals and machine learning algorithms.

The purpose of the work – create and authenticate a technique for calculating the load of the screw press bowl by utilizing a sound signal and employing machine learning techniques.

Problem Statement

The determination of the fullness of the screw press hopper plays a critical role in optimizing the efficiency of oil production and ensuring the quality of the oil produced. However, current methods of establishing this fullness, based on the weight measurement of the oil extracted, can be inaccurate due to variable weight of oil at different stages of extraction, oil loss within the system, heterogeneity in the texture or moisture content of the material, and environmental factors that can change the properties of the oil or material. There is also a lack of precise calibration of the existing measuring instruments leading to inconsistent results, not to mention the time and resources needed for maintenance and calibration. Additionally, these systems have limited accuracy and measurement capabilities which curtails their utility in gauging the fullness of the oil extraction bowl. Therefore, while the use of more accurate devices and improvements in seed squeezing and processing technologies can partially address these issues, there remains a considerable gap in the development of dynamic, self-evolving, and automated techniques that can accurately determine the fullness of the screw press hopper under varying conditions.

This study aims to bridge this gap by suggesting a novel approach for determining the screw press hopper fullness using machine learning methodologies. By leveraging the characteristic acoustic signals generated during different operational stages of the screw press, this study seeks to train a machine learning model that can accurately link the nature of the produced noise signal to the level of the press hopper's fullness. This approach has the potential to automate the monitoring and control process, thereby enhancing the device's efficiency and resource conservation ability, while also setting a foundation for predictive maintenance systems.

Review of Modern Information Sources on the Subject of the Paper

An analysis of the existing literature shows the widespread use of machine learning and sound analysis for monitoring and control, including. In this article [3] authors propose the use of artificial intelligence to detect traffic noise and improve data quality. The paper [4] analyses the input data for machine learning algorithms, such as the application of different cough sounds for disease tracking. The study [5] develops a cough detection system using sound data obtained from Arduino 33 BLE Sense and Edge Impulse. Arduino Nano 33 BLE Sense has built-in sensors that will allow collecting information. The cough sound read by the microphone is processed using Edge Impulse machine learning.

Based on the analysis of source [6], models trained to recognize music and sounds show potential for application in machine diagnostics. The YAMNet network has shown the effectiveness of detecting bearing faults. Applying knowledge of sound and music recognition for fault diagnosis is effective, especially in conditions of limited data. The article [7] explores the use of machine learning to monitor screwdriving and pressing processes, which allows for defect detection and reduced costs.

The microcontroller Arduino [8] allow the creation of nodes within an IoT network, the reading of physical values, the transmission of these values for processing, and the control of electronic components and machinery in the physical realm. In this scholarly investigation [9], the researchers explore the advantages of combining the Internet of Things with artificial intelligence models to precisely ascertain moisture levels in diverse circumstances.

Arduino is a good choice for a smart home controller [10] due to its versatility and cost-effectiveness. It offers a flexible and affordable platform [11] that enables the automation and control of a wide range of devices and systems within the home environment.

The Internet of Things (IoT) [12] presents numerous possibilities across diverse sectors. Agriculture plays a crucial role in the economy [13], necessitating meticulous monitoring and maintenance. In this scenario, the utilization of efficient models and the Arduino controller enables the optimization of resource utilization and enhances productivity. Machine learning (ML) and audio analysis [14] are robust methodologies for addressing a wide range of tasks. ML enables the examination of extensive datasets and the identification of intricate relationships, thereby facilitating the development of predictive models and the optimization of processes. Audio analysis [15] enables the detection of noise, monitoring of equipment health, and recognition of events and patterns. By integrating ML with sound analysis [15], one can achieve enhanced precision and dependability in resolving diverse tasks.

Results and Discussions

Monitoring the operation of a screw press for oil production is an extremely important task. Effective monitoring allows you to ensure the optimal efficiency of the press, increase production capacity and maintain the high quality of the produced oil. One of the methods of assessing the load of the screw press is the use of acoustic signals that occur during the operation of the press. During the oil extraction several processes take place, such as crushing of the seeds, compression and extraction of the oil. Each of these processes has characteristic acoustic signals that can be analysed to determine the condition and efficiency of the press. The sound produced during the operation of the screw press can provide important information about its condition and filling level. Comparing the audio signals obtained during different press conditions can help to train a model to detect these conditions.

The test utilized an oil screw press, which maintained a maximum power consumption below 1500 W when operated with an alternating voltage supply of 220 V at a frequency of 50 Hz [17].

Fig. 2. Oil screw press LTP200 [16]

It is important to mention that there may be some differences in the sound generated by the screw press, depending on factors such as load level or screw speed. For example, when the screw press is full (Fig. 2) or overloaded, the sound may be muffled or saturated, due to the larger amount of material being processed. By comparing the acoustic signals received during different press states (Fig. 3, Fig. 4), a classification model can be trained to automatically determine the state of the press and detect whether it is full. The model can analyse the characteristics of the sound signal, such as frequency, amplitude, spectral properties, etc., and draw conclusions about the condition of the press based on this.

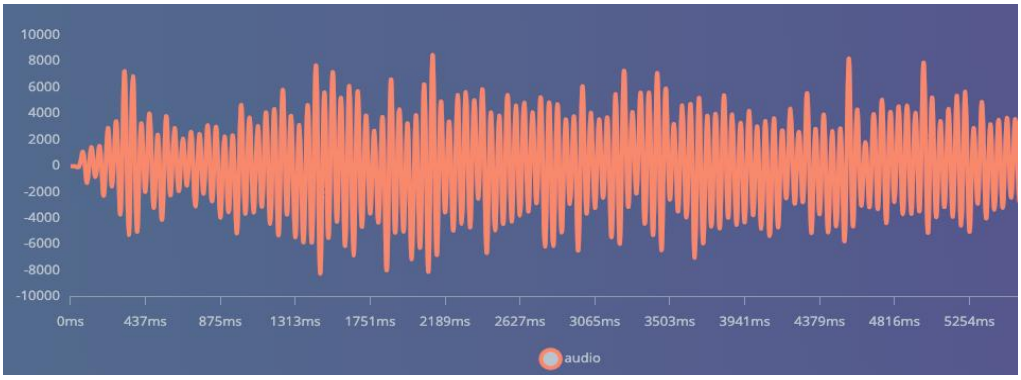

Fig. 3. Waveform of screw press work with seeds.

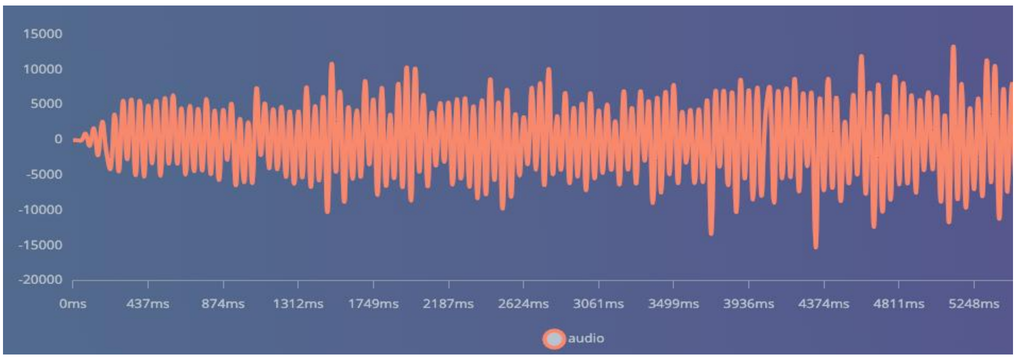

Fig. 4. Waveform of screw press work without seeds.

In order to teach a ML model how to categorize noise from screw press the initial step is to provide it with an audio sample that it can learn to identify (Fig. 5). The technique known as supervised learning is employed to train the model. The model undergoes training in supervised learning using pre-existing data and is informed whether its predictions are accurate or not during its "practice" sessions. This process is commonly referred to as the training process. In the case of supervised learning for noise (audio) classification, objects are labeled with their respective names in advance, which will become evident when we delve into the audio recording section.

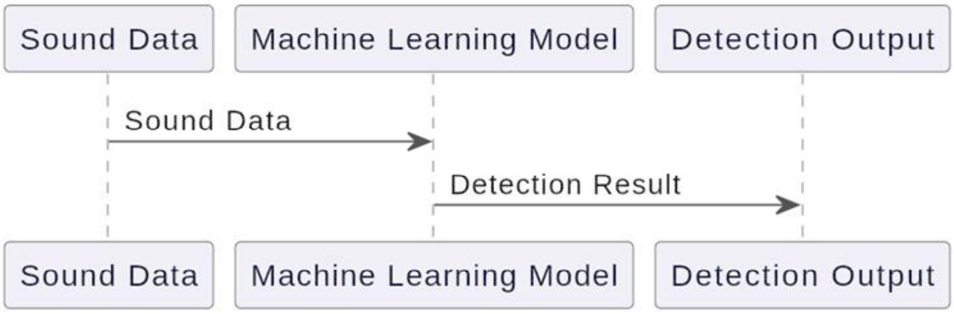

Fig. 5. UML diagram for Smart screw oil press hopper loudness detection

Based on sound data analysis, 2 different spectrum plots were identified (Fig. 6, Fig. 7). The first spectrum plot represents the working sound of screw press without seeds, and second one – with seeds.

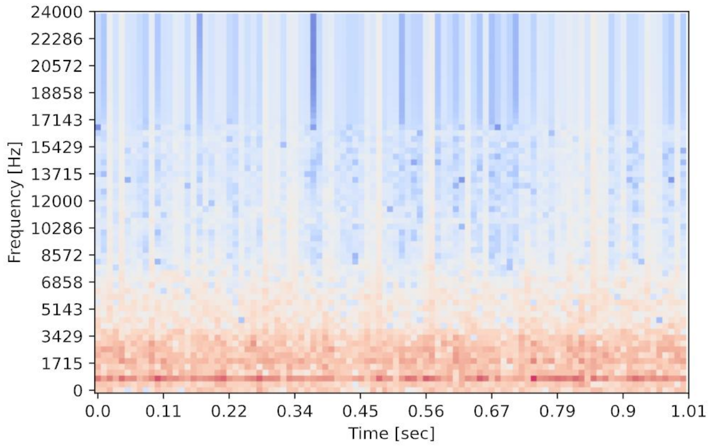

Fig. 6. Spectrum plot of screw press work without seeds.

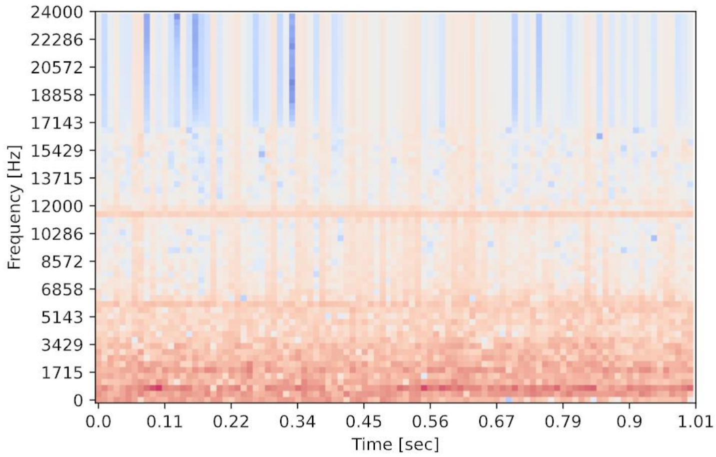

Fig. 7. Spectrum plot of screw press work with seeds.

ML tools Arduino [17] is a powerful tool that provides the ability to train machine learning (ML) models and deploy them to Arduino microcontrollers after successful training (Fig. 8). This tool allows developers to create intelligent devices that can perform data analysis and make decisions based on the collected data without the need to connect to cloud services or external servers. ML tools provide a variety of machine learning algorithms to analyse data and build models, such as classification, regression, clustering, and more. This instrument provides a broad array of opportunities for the development of various intelligent devices based on Arduino. It enables the utilization of machine learning's power directly on the microcontroller, thereby enhancing their autonomy and efficiency.

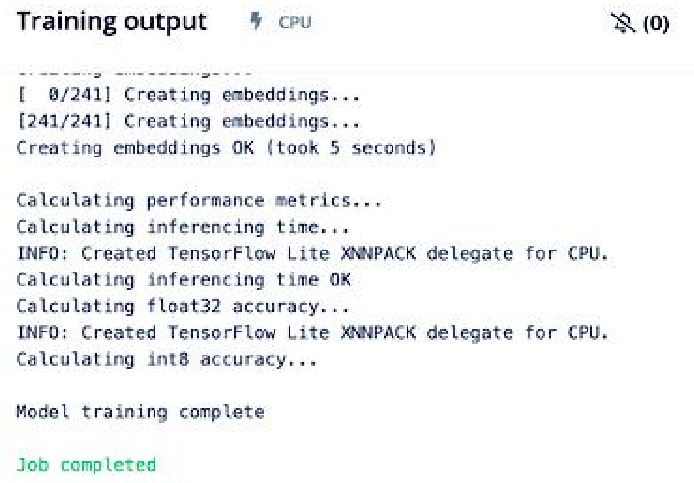

Fig. 8. Training output

Conclusions

Machine learning is one of the effective tools for determining the loading of the seed hopper of a screw press for oil extraction by analysing the sound signals created during the operation of the press. Research shows that the noise generated during the operation of the press contains useful information about the state of the oil pressing process. The use of machine learning algorithms allows to process these sound signals and establish a connection between the nature of the noise and the level of loading of the press hopper.

The advantage of this approach is the possibility of automating the process of monitoring and controlling the operation of the press, which allows to increase the efficiency of the device and its saving of resources. In addition, the analysis of the noise from the press can serve as a basis for the development of systems for predicting and preventing possible breakdowns or malfunctions in the equipment. Despite these advantages, it is important to correctly configure machine learning algorithms and constantly monitor their accuracy and reliability. It is also important to develop models that can adapt to the conditions under which the press works.

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ВИЗНАЧЕННЯ ЗАПОВНЕНОСТІ ЧАШІ ШНЕКОВОГО СМАРТ ПРЕСА ІЗ ВИКОРИСТАННЯМ МАШИННОГО НАВЧАННЯ

Отримано: березень 20, 2024 / Переглянуто: березень 28, 2024 / Прийнято: квітень 01 , 2024

Анотація. Постановка проблеми. У цьому дослідженні розглядається проблема точного визначення заповненості чаші шнекового преса для оптимізації процесу відтиску олії. Наявні методи вимірювання на основі ваги або об’єму часто можуть давати неточні результати через змінну вагу олії на різних етапах екстракції, неоднорідність матеріалу, вплив навколишнього середовища та неточне калібрування приладу. Мета. Дослідження пропонує нове рішення за допомогою застосування машинного навчання, зокрема з метою розробки та перевірки методики, яка використовує акустичні сигнали для розрахунку завантаженості чаші шнекового преса. Методологія. Для реалізації цього рішення в дослідженні використовуються кількісні дослідження, збір і аналіз даних, машинне навчання. Метод заснований на обробці аудіоданих, отриманих від мікрофонів, розташованих біля шнека, і використання алгоритмів машинного навчання, таких як класифікація звуку. Процес навчання моделі відбувався із використанням інструменту Arduino. Результати. Результати цього дослідження, які сприяють ефективному аналізу даних за допомогою інструментів ML, демонструють, що рівень заповнення чаші шнекового преса може бути ефективно визначений за допомогою звукових сигналів і відповідних алгоритмів машинного навчання. Новизна. Безперечна перевага цього підходу полягає в його здатності автоматизувати процес моніторингу та оперативного керування шнековим пресом, тим самим покращуючи ефективність пристрою та економію ресурсів. Практична значущість. Запропонований підхід дозволяє автоматизувати процес визначення наповненості чаші та контролювати стан шнека за його звуковими характеристиками. Це рішення може бути використано в олійній промисловості для підвищення продуктивності шнекових пресів. Це дослідження підкреслює перспективність програм машинного навчання та потенціал майбутніх досліджень, спрямованих на покращення адаптивності моделі та розробку систем прогнозованого обслуговування. У подальшому це може революціонізувати моніторинг та операційні процеси в олійній галузі.

Ключові слова: Arduino, витискання олії, автоматизація, розумні технології, звук, машинне навчання.