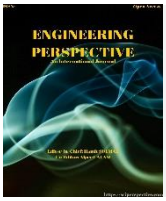

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Autonomous Feed Pushing Robot Design and Manufacturing

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ABSTRACT

The inability of animals to reach the food during feeding causes stress and may lead to a decrease in milk yield. At this point, adequate nutrition of animals in farms is very important in terms of milk yield. In this study, the design and manufacture of an autonomous machine that can be used in animal farms and facilities has been carried out. The functions of the device were determined and the main chassis and the parts were designed. First, the main chassis, which forms the body of the device was designed and electronic components were assembled on it. Feed is pushed by means of the drum, which is mounted on the main chassis with the connecting arms and located outside. The device was produced with the designed machine body. The machine can provide forward-backward, rotational and drum movements. It has a mass of approximately 80 kg and is equipped with three 12 V direct current electric motors. The device, which can be operated with Arduino and interface program, can move autonomously. The machine designed and manufactured has been tested in the animal farm.

Keywords: Autonomous, Feed pushing robot, Milk yield, Labor

History
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1. Introduction

Autonomous era is rapidly spreading with developing technology in the world. The tools and equipment that we use frequently show that the autonomous age has developed. With the rapid developing of the industry 4.0 era and the Industry 5.0 era, the autonomous is frequently encountered every day [1-4]. Most of the devices we see around us are actually examples of the rapid development of the autonomous era. Autonomous technologies are widely used in the automotive industry, aviation, textile, agriculture and livestock fields [5-9].

One of the biggest benefits of autonomous technology is eliminating man power. It is used as a useful purpose by eliminating man power in many areas and increasing the technological development and welfare levels of countries thanks to artificial intelligence. There are serious developments in many areas, from driverless cars to space technology and defense industry in autonomous technology. Protecting human health and causing less harm to the environment and atmosphere are some of the most important advantages of this technology. With this developing technology, time, energy and labor can be saved in the area where it is used [1-9]. Due to the increase and development of animal husbandry in the developing agricultural sector of our country in recent years, animal breeding in farms is increasing day by day. The nutritional needs and other needs of animals are met with the contribution of man power. At this point, the human factor in the agricultural sector comes first and the need for man power increases. However, this brings additional labor costs. As mentioned before, the cost of equipment used in farms and animal facilities is quite high, and the employment of labor brings extra costs. So, owners and farmers cannot afford this costs. Because, manpower is always needed to push the feed in front of the animals resulting in extra expense for the farm. Therefore, the usage of autonomous technologies in the field of agriculture comes to the fore [4-9].

Import and export of milk and dairy products in our country are one of the most important parameters in the agriculture and livestock

sector. The total number of animals milked in our country is approximately 33 million in 2020, and milk export is around 517 million dollars [10-12]. Animal breeding, animal care and the amount of milk obtained from animals are important issues that we encounter in the field of agriculture in the world. In order to increase the milk obtained from animals, it is necessary to meet the nutritional needs and care of animals in the most efficient and healthy way according to environmental conditions. Keeping the environment clean and spacious, timely and appropriate feeding and usage of some vehicles such as tractors or any other machines according to time and conditions are very important for the milk yield and health. Feeding animals with the help of tractors not only emit harmful exhaust gases but also produces high level of noise due to internal combustion engines. On the other hand, necessity of fuel is required in case of usage of internal combustion engines. The released harmful gases affect adversely the health of both farm workers and animals. At the same time, equipment used with man power can cause animals to be afraid. One of the most significant problem is poor nutrition, because animal moves the feed away from its front. Worry about not being able to keep up with the food can also cause stress in animals. As a result, it is seen that milk yield decreases in malnourished animals. In the mean time, it has been observed that the number of heart beats is higher during eating than standing [13-16]. It is even known that milk yield is affected by stress experienced by animals during feeding [13-18]. Residual feed is another problem in animal farms. Residual feed can be also eliminated with devices that automatically push feed in front of animals without the need for manpower. Activities and development studies that will increase productivity in the animal husbandry sector are of great importance in our country, where there are approximately 18 million cattle [19,20]. At this point, milk yield, which provides great benefit in cattle breeding, is one of the most important arguments for our country in this field. It is seen that the share of cattle in milk production has exceeded 90% as of 2017 [10-12].

When time schedule of cattle was examined, it was determined as 42.4% resting, 11.1% standing, 32.3% feeding, 1.6% drinking water, 6.3% walking, 1.7% other behaviors and 4.6% milking. As it is seen that feeding is a big part of it. At this point, animals were observed with cameras for 24 hours. It has been found that high productivity was determined on animals, which were kept away from stress [21]. It was also presented that the factors that cause stress in animals should be carefully examined and practices aimed at eliminating these factors should be implemented. It is seen that deterioration of hygiene in the environment where the animal lives, decrease the amount and quality of feed and the loss of weight of animals are natural responses to stress [17,22]. At the same time, stress negatively affects the lactation period. It negatively affects milk production by causing a decrease in oxytocin hormone production during stress [18, 23-29].

As stated earlier, labor cost is rather high for farmers. It was showed that the largest expense ratio after feed costs is temporary workers in the farm. It is seen that this value is 1.98% of the enterprise average [30]. It is seen that these costs can be reduced with the usage of some autonomous devices.

The usage areas in farms change according to the parameters of produced autonomous robots and their types. Autonomous robots can run according to nutritional needs of animals in the farm. They perform the tasks that they have to do in specified time intervals. They also take on the tasks instead of human with the help of their software resulting in reducing environmental pollution. Animal husbandry can be done efficiently with robots that are operated according to farm conditions without harming the environment and animals.

There are autonomous devices that have been used to push the feed in front of animals or devices that perform different tasks in agriculture and livestock industry. They have mobile applications and have battery-powered systems [7,31-35]. However, these products are quite expensive to buy. In this study, the design and manufacture of an autonomous feed pushing robot working with a direct current battery was carried out. It was aimed to design and manufacture an economical and efficient feed pushing robot. Feed can be moved away from animals while feeding. The autonomous feed pushing robot will be able to push feed in front of the animals with the help of rotating plate and rubber. The produced machine can be used in covered farms with concrete floors. After completing its mission, the autonomous robot can come to the charging station to recover its energy and prepare for the next tour. The manufactured robot is autonomous and can eliminate the need for labor. It was also aimed that produced autonomous robot will be a device that users and farmers can easily buy and use economically. This will result in substantial financial gain.

2. Material and Method

In this study, autonomous feed pushing robot was designed using Solidworks. Designed mechanical chassis and sheet drum are seen in Figure 1. Manufactured device can be divided into two sections called mechanical and automation system. Mechanical section consists of main frame, shaft, whells, brackets, iron blade and profile, chain gear mechanisms, sheet drum and top cover. On the other hand, there are three DC electric motor, 12V DC battery, rotary encoder, relay, potentiometer, sensor, limit switches, Arduino microcontroller, safety button and control panel in the automation system.

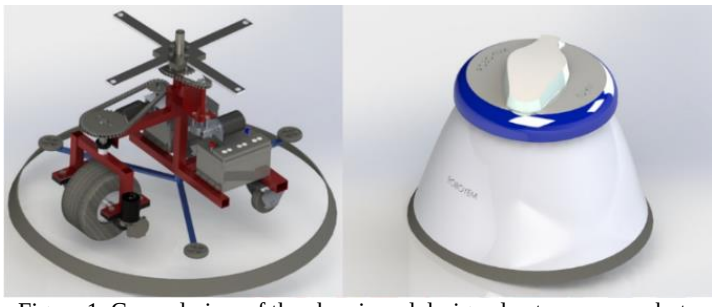


Figure 1. General view of the chassis and designed autonomous robot for the feed pushing

Main frame of the device and some components are seen in Figure 2. Designed device can move forward, backward, right, left, and the drum can be rotated using DC electrical motors. The movement of the mechanism is provided via front whell powered by electric motor.Driving electric motors were powered by 12V DC battery in automation system. The automation system generally consists of sensors, safety system, power supply and control panel parts as seen in Figure 3. Relays which are economical and practical method were utilized to drive DC motors. Microcontroller has been used in order to control relays. In addition, progress of the distance and position of the steering should be determined. Potentiometer and rotary encoder

were used to do these tasks. Dead reckoning method has been applied using distance, time and direction information. The signals produced by the rotary encoder and potentiometer can be received by the microcontroller and the electric motors can be driven.

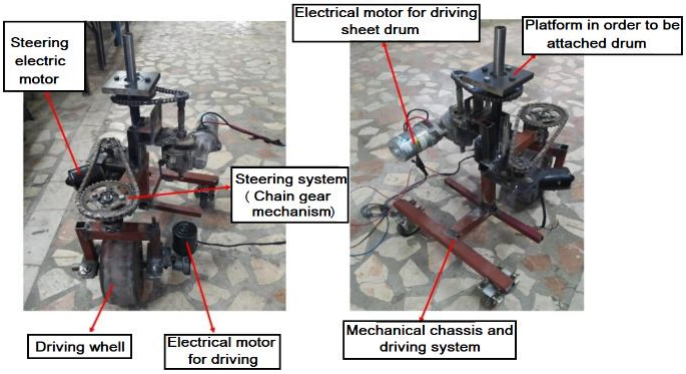


Figure 2. Mechanical main frame of the device and some components

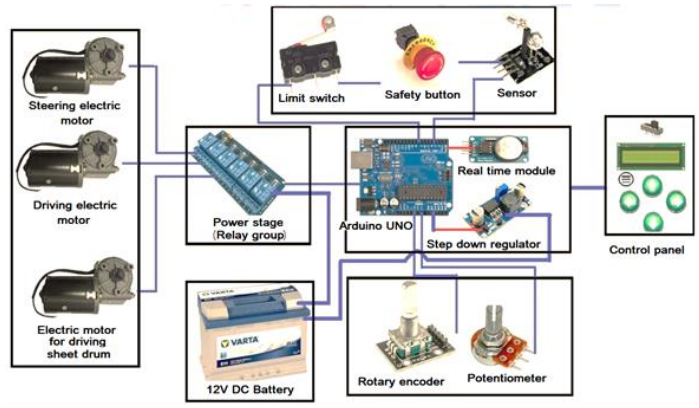


Figure 3. Automation system and components

The automation system of the autonomous feed pushing robot has manual and operator modes and the robot can be operated in both modes. It can be controlled by a wired controller in manual mode. In manual mode, the route to be followed in the facility is firstly shown to the robot. With this tour, data from the rotary encoder and steering position sensor can be recorded by the robot during route determination. Registration ends at the last charging station. If the autonomous robot is in operator mode, automation algorithm starts at the lap times entered into the microcontroller. The encoder and steering position data previously saved in the memory can be compared with the new data and the motors can be driven. The route within the facility starts at the charging station and ends at the charging station. After the autonomous robot completes the designated tour, it can come to the charging station where the batteries can be charged. User can be able to program the robot without the need for a technical personnel. Block circuit diagram for driving motors is presented in Figure 4. In addition, an algorithm has been created for the control and automation of the robot. The automation algorithm of the autonomous robot is shown in Figure 5.

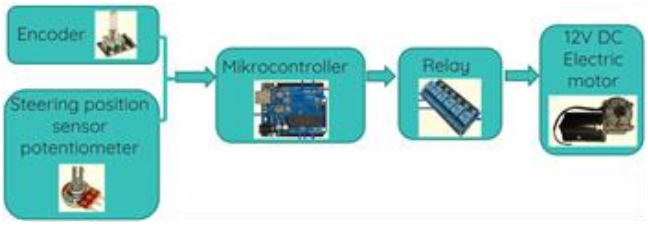


Figure 4. Block circuit diagram for driving motors

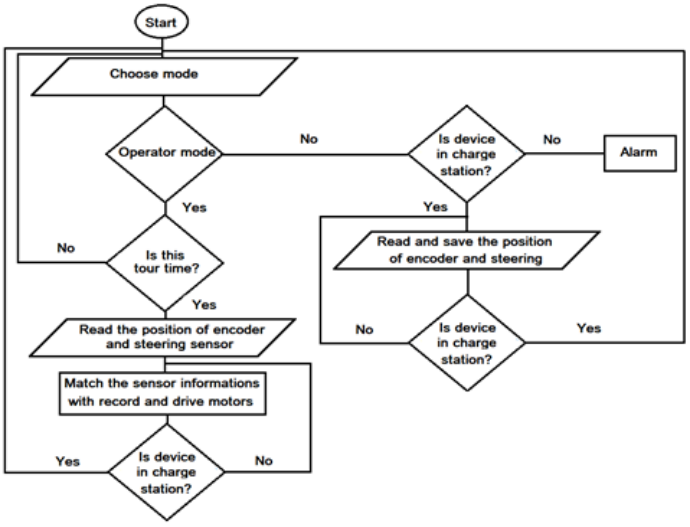


Figure 5. Autonomous feed pushing robot automation algorithm

3. Results and Discussion

Nutrition of animals is critical for milk yield and animal health. It is essential to have sufficient feed in front of the animals, especially in farms and facilities where there are many animals. There is now a need for a labor force to reduce feed and adequate nutrition. However, labor force requires extra costs for this task in the animal farms. Besides, extra time is spended for pushing feed to the front of the animals. Figure 6 shows the schematic representation of the feed pushing.

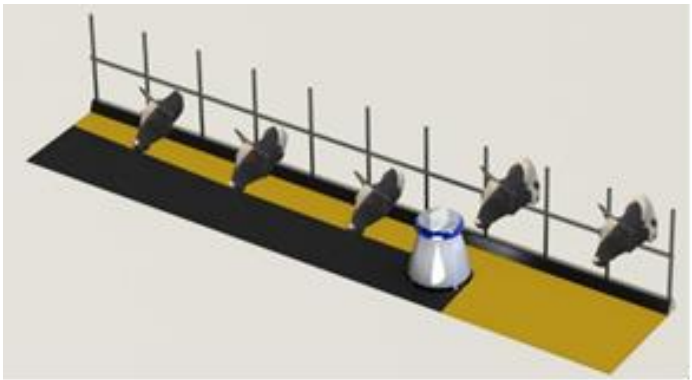
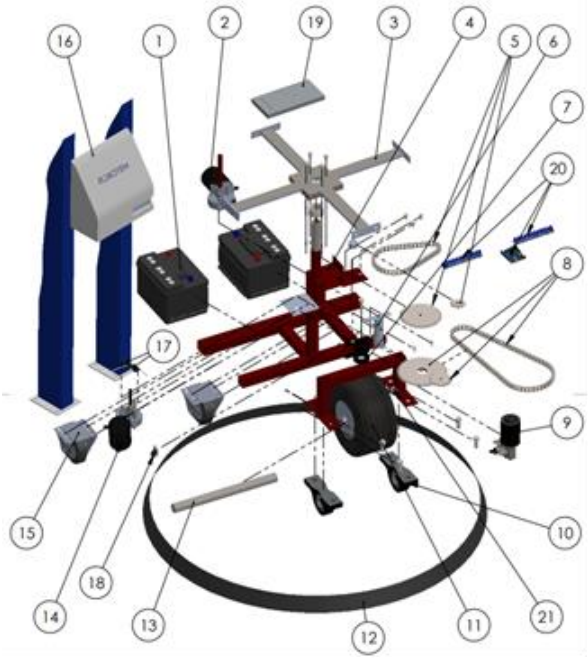


Figure 6. Schematic representation of the feed pushing

The agriculture and livestock sector in our country is developing day by day with technology. With the developing technology of our country, it is very important that the development in every field is through the production of domestic and national products. It was also

aimed to design original machine and produce in this study for pushing feed. Rail systems can be used to push feed in animal farms. However, maintenance costs are high. On the other hand, when machines with internal combustion engines that perform this process are used, there is fuel consumption and harmful gases are released. At the same time, manpower is needed to push the feed. Since the system is electric and autonomous, these problems are eliminated in the current study. The design of the machine has been created taking into account the strength and the characteristics of the work to be done. Attention was paid to the weight, balance and ability to carry the parts on the device. It is important that there are no mechanical problems such as wear and friction during the usage of robot. Figure 7 exhibited the explosion view of the autonomous feed pusher robot.



1. Battery 2. Steering electric motor 3. Drum connection cross 4. Connection bracket 5. Steering gears and chain 6. Front wheel hitch pin 7. Front wheel hitches 8. Drum drive gears and chain 9. Forward-reverse electric motor 10.Front axle joint 11.Drive wheel 12.Rubber hoop 3.Front axle 14.Drum electric motor 15.Rear Wheel 16.Charging station 17.Switches limiting left and right movement 18. Steering position sensor 19.Remote control 20. Autonomous control system 21. Encoder

Figure 7. Explosion view of the autonomous feed pusher robot

The most important side of this study is to design and manufacture device that uses less energy. For this purpose, electric energy is utilized for pushing feed. In this case, the determination of the operation current is critical. So, each electric motor uses about 3 amper current. If 72 Ah DC battery is used, all electric motors can be run at about 8 hours with full charge. So the determination of required power is essential for electric motors. On an average-sized farm, animals are fed about 5 or 6 times a day. One period can be completed via the stored energy thanks to the used 12V DC battery. When each feeding takes about 15 minutes for an average sized farm, machine can easily do many tours. As it is known, required power can be calculated according the weight and motions of the machine as mentioned below.

$$P = T.\omega \quad (W) \tag{1}$$

$$\omega = \frac{2\pi n}{60} \quad (rad/sn) \tag{2}$$

$$P = F.V \quad (W) \tag{3}$$

Where P, T and ω refers to power, engine torque and angular velocity. F and V defines the force and velocity [36,37]. Figure 8 shows the manufactured feed pushing robot.

Figure 8. Manufactured feed pushing robot

4. Conclusions

Autonomous feed pushing robot provides a more efficient and more comfortable opportunity by eliminating human power and eliminating the damages and losses that may occur. It saves both time and efficiency, and offers a more comfortable technology that can adjust itself to environmental farm conditions. In this study, it was aimed to design and produce autonomous feed pushing robot. Manufactured device was tested in an animal farm. Each feeding process can take about 15 minutes on an average sized farm. If 5 periods are taken into account 450 hours of labor per year can be saved. If a farm that produces 100 liters of milk per day is considered, increase in production milk 3-5 liters per day and a total 1100-1800 liters in a year will be estimated. Total cost of the autonoumus feed pushing robot is about $600 which is very less compared to the other brands. Malnutrition can be prevented with designed device and the efficient usage of manpower will be ensured. The amount of residual feed decreases in front of the animals. In addition, labor costs can be reduced for pushing feed. Since manufactured device is not so expensive, it can be used in small and medium-sized farms apart from in large farms. According to the findings of this study, the robots used by the farmers around the world in their farms are rapidly becoming widespread each passing day.

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Nomenclature

F	Force (N)
DC	Direct current
P	Power output (W)
T	Torque (Nm)
V	Velocity (m/s)
ω	Angular velocity (rad/sn)
n	Engine speed (rpm)

Conflict of Interest Statement

The authors declare that there is no conflict of interest in the study.

CRediT Author Statement

Ahmet Uyumaz: Conceptualization, Supervision, Project administration, Writing-original draft, Validation, Writing-review&editing **Şenol Güzel:** Conceptualization, Supervision, Project administration **Abdullah Köse:** Validation, Project administration, Data curation, Methodology Formal analysis **Sinan Satılmış**: Methodology, Funding acquisition, Validation, Software **Burak Polat:** Funding acquisition, Investigation, Resources **Oğuzhan Karakaş:** Methodology, Investigation, Resources **Yiğitcan Küçükçelen:** Data curation, Investigation, Methodology

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