

Microcontroller implementation in precision planting: A review

Abstract

Precision farming, also known as precision agriculture, is a crop management method that optimizes agricultural production by utilizing technology and data for precise placement of seed, fertilizer and pesticides. It enhances increase crop yields, reduce waste, and reduce environmental impact by applying the appropriate amount of inputs, such as seed, water, fertilizer, and pesticides for each crop. Farmers can reduce expenses by reducing the usage of expensive inputs while increasing yields and crop quality by employing precision farming techniques. Commercially available planters normally use mechanical metering systems which have many limitations including, skidding of the wheel, non-uniform seed rate, wastage of the seed and higher maintenance cost. It is evident from recent researchers that irregularly in seed placement, which is generally caused due to wheel slippage and seed metering systems powered by electric or hydraulic motor can maintain accurate seed placement and can work at higher speeds compared to traditional planters.

Keywords: Precision planting, Microcontroller, Sensor and Automation

Introduction

A planting machine's main goal is to plant seeds at a specific depth and spacing inside a row. Seed metering devices include fluted feed type, internal double run type, cup feed type, inclined plate type, cell feed type, brush feed type, auger feed type, picker wheel type, and variable orifice type in seed drills or planters. (Varshney *et al.* 2004). These apparatuses usually need a ground wheel for transmission of the power, and as a consequence, planting accuracy cannot be safeguarded because of the presence of ground wheel slippage and chain vibration especially at higher forward speeds (Lie *et al.* 2015).

Several types of planters and seed drills have been developed but the problem continues, like the missing of seeds, overfilling (**Baral et al. 2019**). Mechanical metering mechanisms have proved to be supportive, but they do not provide desired precision and cause an excess in seed due to the loss in mechanical transmission (**Aware and Aware, 2014**). Another drawback of mechanical metering devices is the bulkiness of the system. In a mechanically driven system there is the lack of communication of seed placement between row-unit on an implement. The Mechanical driven system regulates mainly the seeding population, but not the actual timing and placement of the seeds (**Iacomi and Popescu, 2015**). It is observed during operation, that factors such as crop residues, stubbles in the field, uneven topography, and high resistant torque on the ground drive wheel result in the negative slippage of the ground wheel (**Namdeo et al. 2020**).

Kepner et al. (1987) demonstrated that non-uniform seed placement would reduce final crop yield. Microcontroller seed metering mechanism works with a sensor-built electronic metering system, which improves precision to the work. In this case, the seed rate can be easily controlled with the rpm controller and can be used for a variety of seeds with a change in the seed metering plate, and an electronic metering mechanism may be one of the options to achieve accurate seed spacing with higher efficiency (**Koley et al. 2017**).

1. Working principle and components of electronic sowing/planting system

The electronic system works on the concept that the shaft encoder detects the forward speed and sends signals to the microcontroller in digital code. The microprocessor synchronizes the forward speed of operation with the metering mechanism plate in a 1:1 transmission ratio. The microprocessor sends signal to motor driver module, which is coupled to the rotating electric motor (Fig.1).

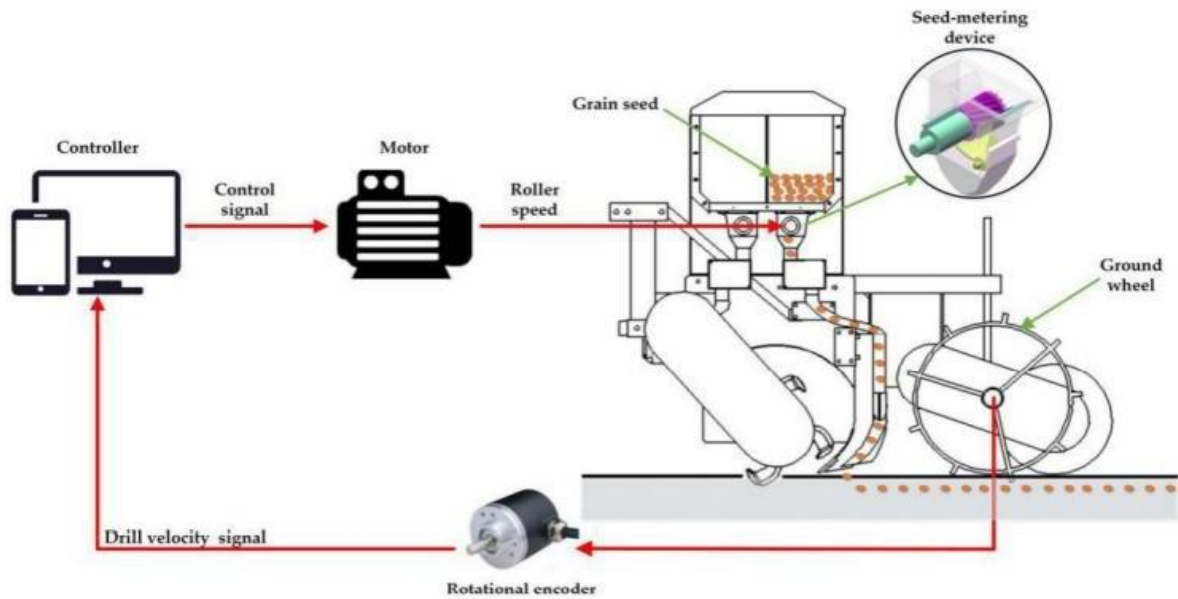


Figure 1. Components of the electronics seed metering system (Liu *et al.*, 2020).

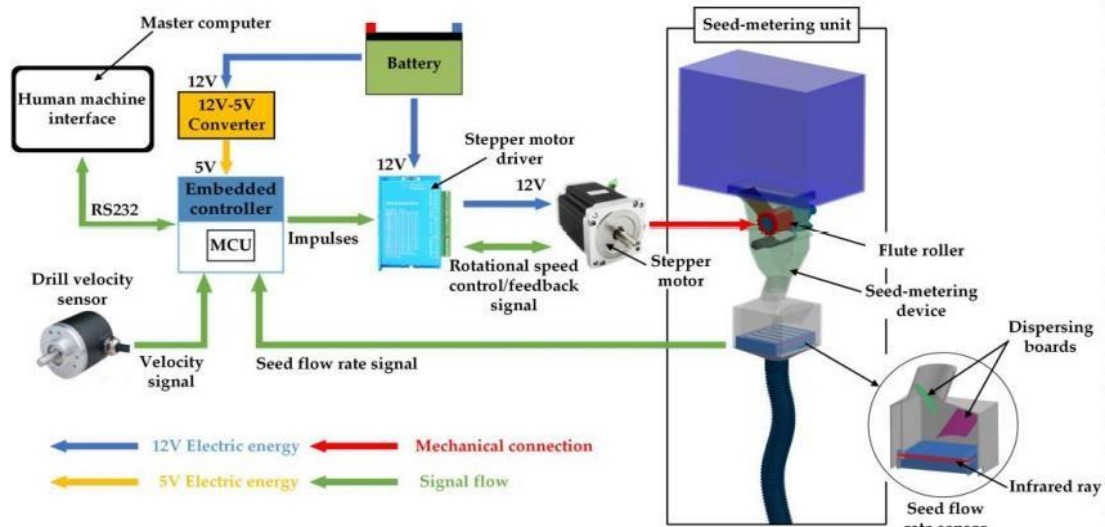


Figure 2. Schematic view of the adaptive seed metering speed control system for a seed-metering unit (Liu *et al.*, 2020).

Liu *et al.* (2020) developed a mechatronic system for a uniformity of the seed spacing that includes an Embedded controller, shaft encoder for measuring travel speed, electric motors, seed box, seed meters, and power supply (Fig.2). The Mechatronics system is powered by a 12-volt tractor battery. An incremental encoder mounted on the shaft of a ground wheel measures the value of travel speed. The encoder emits matching pulses in response to the rotation of the ground wheel, which the controller can use to compute travel

speed by counting the number of pulses received in a given amount of time. Brushless DC motors with three Hall-effect sensors attached on the back for monitoring the positions of the U, V, and W rotors enable current switching for the rotors.

To achieve closed loop control, the three Hall-effect sensors measure the motor speed in real time. The number of seeds can be judged according to the time when the falling seeds shaded the infrared ray. A master computer allows for the inputting of parameters such as seed spacing, wheel slip ratio, ground wheel diameter, and number of seed holes per disc, as well as the display of travel speed and seed plate rotation speed, as well as the sounding of alerts in the event of a system fault. The controller's primary role is to generate a pulse signal with a specific frequency and duty cycle to control seed plate rotation speed dependent on travel speed in order to ensure uniform seed spacing.

2. Analysis of the metering mechanism's performance

The fraction of seed spacings that are greater than or equal to 1.5 times the nominal seed spacing is known as the missing-seeding index (I_{miss}), which shows the percentage of missed seed sites or skips. Multiple index (I_{mult}) includes two or more seeds picked and dropped by the seed metering unit through a single groove in the metering plate, it is the percentage of seed spacing less than or equal to 0.5 nominal seed spacing. The percentage of seed spacing that is more than half but not more than 1.5 times the nominal spacing is known as the quality of feeding index (I_{qf}), and it reflects the percentages of single seed drops. After excluding outliers such as missing-seeding and multiples, precision index (I_p) is defined as the coefficient of variation of the spacing (length) between the nearest seeds in a row that are classified as singles. I_{miss} , I_{mult} , I_{qf} and I_p can be calculated using equation 1, 2, 3 and 4 respectively (Singh et al. 2012 and Li et al. 2015).

$$I_{miss} = \frac{\sum_{i=1}^n \frac{L_i - L_n}{L_n}}{n} \quad \dots(1)$$

$$I_{mult} = \frac{\sum_{i=1}^n \frac{L_i - L_n}{L_n}}{n} \quad \dots(2)$$

$$I_{qf} = 100 - (I_{miss} + I_{mult}) \quad \dots(3)$$

$$I_p = \frac{\sum_{i=1}^n \frac{L_i - L_n}{L_n}}{n} \quad \dots(4)$$

Where

n_1 is number

of spacing $> 1.5S$, n_2 is number of

spacing $\leq 0.5S$

N is total number of measured

spacing I_{QF} is percentage of quality of feed in

dex

S_d is standard deviation of the spacing more than half but not more than 1.5 times the set spacing S in mm.

The research undertaken has been reviewed and more than 100 research papers/articles have been studied. The important researches undertaken by various researchers on electronic seed metering mechanism and use of agricultural robots for seeding operations have summarized in Table 1 and 2 respectively. In addition, results of relevant studies on electronic metering have been summarized in Table 3.

Table 1. Electronic seed metering mechanism

Description	Major findings
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A microprocessor-controlled planter
(Wilkins and Lenker, 1981).

In comparison to a commercial vegetable planter, laboratory tests on a greased belt revealed that the microprocessor-controlled planter metered raw lettuce seeds with fewer errors.

Opto-electronic sensor system for rapid evaluation of planter seed spacing uniformity (Kocher *et al.* 1998)

The opto-electronic system can be used instead of a grease belt test stand to rapidly obtain quantitative evaluation of planter seed spacing uniformity in the laboratory.

Opto-electronic sensor system for laboratory measurement of planter seed spacing with small seeds (Lan *et al.* 1999)

The opto-electronic sensor system missed two seeds and detected two planter seeds out of 170 seed spacing with the medium encrusted sugar beet seed.

Development of proximity distance sensor based electronic metering mechanism for three row planter (Aware *et al.* 2008)

Developed electronic planter was tested in the laboratory. It was necessary to keep the tractor speed constant in order to achieve the desired planter to planter spacing.

Development and functional test of electronic metering mechanism for bullock drawn multi-crop planter (Shinde et al., 2009).	Discusses various electronic seed metering mechanisms components operations; distance sensing unit, check valve activating system with a microprocessor, software program, and solenoid switches with their future possibilities.
Performance monitoring system for precision planter based on MSP430-CT171 (Xia et al., 2010).	100% of the sound-light alarm system and the photoelectric sensor could detect more than 95% seeds passed it.
Development of an optoelectronic monitoring system for crop planter seed metering unit (Hajjame et al., 2011).	Briefly explains the application of an optoelectronic sensor, rotary encoder, amplifiers, microcontroller, and PC.
Development and laboratory performance of an electronically controlled metering mechanism for okra seed (Singh and Mane, 2011).	Deliberates the developed electronically controlled seed metering mechanism achieved sensibly and delivered these seeds quite close to the target seed spacings.
Development of the controller-based seed cum fertilizer drill (Singh et al., 2012).	A brief review of precision farming technologies based on microprocessor and decision support systems for enhancing input application efficiency in production agriculture.
Design, development and evaluation of a mechatronic transmission system for upgrading performance of a row crop planter (Kamgar and Eslami, 2012).	Results of field evaluations showed that mechatronic mechanism decreased multiple index, higher percentage in quality of feed index for planter equipped with mechatronic mechanism and rubber tire.

Design and experimental study of the controls system for precision seed-metering device (**Jianbo et al., 2014**).

The technology would vastly enhance sowing quality, lower leakage seeding rates, and boost output.

A new concept for seed precision planting (**Iacomini and Popescu, 2015**)

Electronically controlled seeds singulation devices have a potential to increase productivity and yield dramatically over a mechanical seed metering mechanism.

Design, Development and field assessment of a controlled seed metering unit to be used in grain drills for direct seeding of wheat (**Kamgar et al., 2015**).

Using a constructed seed metering device in a seed drill, precision seeding for the highest forward speed (8 km/h) was obtained in the field with various levels of stubble coverage.

An embedded system for detecting seed flow in the delivery tube of a seed drill (**Raheman and Kumar, 2015**)

The performance of the developed embedded system was evaluated using a laboratory setup at different seed flow rates for wheat and ragi seeds.

Electro-mechanic control system for pneumatic precision corn planters (**Kocabiyik et al., 2016**).

Pneumatic precision corn planter modified with the electro-mechanic control system was tested and found sufficient for corn seeds in this work.

Optimized design and performance evaluation of an electric cup-chain potato metering device (**Kanget al., 2017**).

Briefly explains the electronic control system instead of a ground wheel driven chain to enable fast seeding and precise in-row seeding distance.

Development of electronic metering mechanism for precision planting of seeds (**Koley et al., 2017**)

The seed breakage was found minimum at a lower metering plate rpm. Seed to seed spacing was found to decrease with an increase in metering plate speed.

Detection of flow of seeds in the seed delivery tube and choking of boot of a seed drill (**Kumar and Raheman, 2018**).

The developed system could produce both visual and audible signals to warn the operator for successful showing of wheat seeds both in the laboratory setup and also in a 9-row tractor drawn seed drill.

Development of tractor drawn electronic multi-crop planter cum fertilizer applicator for precision farming (**Bara et al. 2019**)

The sensor system in the machine helps in proper metering of the seeds and thus further reduces the losses.

Microcontroller based seed metering system for precise soybean seeding (**Namdeo et al. 2020**)

Electronic seed metering system enabled the suggested optimum seeding rate, a quick and simple setting possibility, synchronize and real time control, the ability to work under higher speeds.

Design and testing of noval seed miss prevention system for single seed precision metering device (**Nikolay et al. 2022**)

The analysis of experimental results showed no occurring misses at the seed release point when the system was used.

Development of a single-row push type plot seeder with mechatronic seed feeding device for (*Zea Mays L.*) field breeding experiment (**Taba et al. 2022**)

The machine was equipped with mechatronic seed feeding device to provide an efficient way of sowing for every plot and economical machine for lower stage corn field breeding experiment.

Table 2. Research on agricultural robots for seeding operation

Reference	Description
Use of robotic technology for seedsowing in agriculture (Swati et al. 2015).	The energy required for this robot equipment is less than that required for human and tractor-based sowing. There is also reduced seed waste.
Precision agriculture robot for seeding function (Naik et al. 2016)	Developed robot, working is based on the precision agriculture which enables efficient seed sowing at optimal depth and at optimal distance between crop and their rows, specific for each crop type.
Design of an autonomous seed planting robot (Srinivasan et al. 2016)	Seed metering mechanism device exhibits appreciable efficiency in power consumption, making it suitable for the field of
Automated seed sowing agrirobot using Arduino (Umarkar and Karwan kar, 2016).	agriculture. The effects of seed planting operations are precisely observed utilizing various ground contours and performs digging, sowing the seed and cover the ground by closing it.
Design and development of agrirobot for seeding (Pavan et al., 2017).	These seeding robots can be utilized for mass plantation, reforestation, and afforestation in
Robotic vehicle for seed planting and weeding application (Muley and Kandlikar, 2017).	addition to the agricultural process. It carries out the basic activities of farming, such
Sensor and vision based autonomous agrirobot for sowing seeds (Santhi et al. 2017)	as ploughing the field, sowing seeds, and covering the seeds with soil. The proposed robot is a micro planter whose primary task would be to sow seeds at preferred seeding intervals in the field.

Design and implementation of automatic seed sowing robot (Chame *et al.*, 2018).

It relieves the farmer of some of his responsibilities, and the robot will accurately place the seed in the proper field without the need for human intervention.

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Autonomous seed sowing agricultural robot
(**Jayakrishna et al. 2018**)

Developed robot requires less human effort and time with less cost of implementation

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Solar powered autonomous
multipurpose agricultural robot
using Bluetooth/android app (**Ranjitha et al. 2019**)

Developed robot increases the efficiency of seed sowing, pesticides spraying and grass cutting and also reduces the problem encountered in manual planting.

Design and fabrication of smart seed sowing robot (**Kumar and Ashok, 2020**).

Using a cleverly built mechanical mechanism, this technology totally automates the seed sowing procedure. As the seeds are sown, this robot decreases the work and total cost of sowing.

Design of automated seed sowing robot for BT cotton seed (**Nagdeva et al. 2020**)

Design and the working procedure of these seed sowing mechanism and its various components involved for the successful sowing of the BT cotton seed by the robot.

Fog computing -
based seed sowing robots for agriculture (**Lachure and Doriya, 2021**)

Fast AI method and machine learning techniques are used to classify the wheat dataset into different classes with high accuracy.

Arduino board-
based wireless controlled seed sowing robot (**Sugadeva et al. 2021**)

Robot can manage to plant the seed up to 2-5cm

depth. Different tasks of the robot are controlled by an android application installed on a smartphone.

Developed equipment we used ploughing rod, water pump and seed sower with land levelling attachment.

Automated seed sowing robot (**Vimal et al. 2021**)

Robot that can solve such problem measure the distance between seed that lead to a

Design and development of an agricultural robot for seed sowing, water spray and fertigation

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<p>(Fadhaee <i>etal.</i> 2022)</p> <p>Design of automatic seeds sowing machine for agriculture sector (Kumare <i>etal.</i> 2022)</p> <p>Lot based smart agriculture and automatic seeds sowing robot (Narasimman <i>etal.</i> 2022)</p> <p>Design and development of solar powered autonomous seeds sowing robot (Shanmugasundar <i>etal.</i> 2022)</p>	<p>wastage of water, determined the plants need of fertilizer by using soil PH sensor.</p> <p>Developed machine aim to automate a highly labor-intensive task for farmers lacking the financing resources to afford traditional farm machinery.</p> <p>The ultimate objective of seed planting using improved sowing equipment is to achieve precise seed distribution within the row.</p> <p>A ploughing machine is attached to the machine, which digs the soil for sowing and then, seeds are sowed on the basis of the revolution of the wheel.</p>
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Table.3 Results collected from several electronic studies

Reference	Speed (Km.h ⁻¹)	Results			
		I _{qf} (%)	I _{mult} (%)	I _{miss} (%)	I _p (%)
Onal and Onal, 2009	1.8–7.2	91.30	2.90	5.80	---
Taghinezhad <i>et al.</i> , 2013	0.9–3.6	89.72–93.43	2.52–7.23	2.81–7.26	---
Li <i>etal.</i> , 2015	9–12	89.93–94.23	---	2.49–5.03	17.85–18.80
Rajaiah <i>et al.</i> 2016	2.0	88.1	---	6.1	---
Chunling <i>etal.</i> 2017	10.0	92.04	---	4.82	---
He <i>etal.</i> , 2017	8.6–13	96.9–98.81	---	1.19–3.1	14.38–16.04
Hao <i>etal.</i> , 2017	3–12	95.1–98.1	0.2–0.7	1–4.2	---
Cay <i>etal.</i> , 2018	5–10	90.63	0–1.73	8.44	8.79–22.14
Thokale <i>et al.</i> 2019	4.5	89.93	---	5.08	18.80

Khura et al.	0.65	89.54	---	---	---
2019					
Hensh and Ra	0.84	93.75	0	6.25	---
heman,2022Wa	5-13	---	---	---	16.72
ng et al.					
2022					

Summary of research on electronic seed metering system

The quality of feed index (I_{qf}) of the seed-metering device rapidly increased as the working speed of the operation increased, with increasing miss index (I_{miss}) and precision index (I_p), and greater divergence from the average seeds spacing. With increasing speed, the multiple index (I_{mult}) reduces. According to the experiments, precision planters equipped with electronics systems demonstrated higher seeding uniformity across all seeding technologies, with I_{qf} , I_{miss} , I_{mult} , and I_p ranges between 88.1 and 98.81, 1 and 8.44, 0 and 7.23, and 8.79 and 22.24% ranges, respectively, at travel speeds of 0.65 to 13 kmh⁻¹ (Table 4). Thus, microcontroller-based seed metering system could be one of the possibilities to achieve proper seed spacing with increased planting/seeding efficiency and reduced due to increased seeding speed.

Conclusions

- The advantage of the microcontroller-based seed metering mechanism is more obvious especially when the operating speed is more than 13 kmh⁻¹.
- Precision index of the seed metering mechanism increased with increase the operating speed of the machine.
- Use of electronic for seed metering mechanism may be one of the options to achieve accurate seed spacing with high efficiency.
- Wear and tear of various parts can be reduced considerably through use of electronic seed metering system.
- Smart and automated sowing of seed using a robot reduces the labor requirement and also reduces

drudgery associated with planting operations.

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- Tremendous time saving is possible through automation in sowing/weeding field, standard can be easily met and efficient and effective farming can be performed with increased productivity.

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