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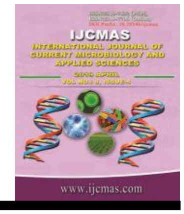

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Mechatronics Application in Precision Sowing: A Review

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In agriculture profession high output is demanded with limited resources and machines are the costlier investment to the agriculture for a marginal and poor farmer. The accuracy and precision of an agricultural machine can be increased using the electronics and computing systems however it increases the cost of the machines. In spite of costlier investments, many researchers have been conducted the study on mechatronics application in precise sowing operation in recent years. Mechanical planters have problems of ground wheel skidding and vibration in the mechanical transmission that affect the hill to hill spacing. From the review, it was concluded that the mechatronic driving system performed better than mechanical driving system in both tilled and non-tilled fields. The increase in uniformity of seed placement was also reported. Thus, mechatronics based seed placement technique was found a better way to achieve accurate seed spacing with higher efficiency in planting. This paper reviews on the mechatronics and its application in precision planting.

Introduction

There are different methods such as broadcasting, dibbling, sowing behind country plough, seed drill and pneumatic planting for seed placement. Out of these methods, seed drill and pneumatic planting methods are more precise. Seed singulation capability of pneumatic planter is higher however it requires more energy. Seed drilling is most common method for cereals and pulse crops. In seed drill different type of metering mechanism are used for seed singulation. The seed drills are modified with seed metering mechanism for more precise singulation. These machines are called planter. Different types of seed mechanism are used for singulation in planter. These are variable orifice, fluted roller, internal double run, inclined plate and cup feed type. These mechanisms generally require ground wheel for transmission of the power. Due to load on ground wheel for power transmission to metering mechanism, the ground wheel skidding is observed. This skidding is responsible for non-uniform seed placement. Nowadays, agriculture requires new monitoring and control equipment and embedded systems for agricultural tractors and implements. The concept of intelligent instruments is one of the key reasons for this trend: instruments with embedded microprocessors providing the capabilities of self-calibration, self-diagnosis and local analog-to-digital and digital-to-analog conversion. The digital transmission of data also increases reliability due to automatic error detection and correction. These distributed systems are composed of several devices like sensors, actuators, control elements and supervision and control units, all of them intercommunicating in real time. To overcome ground wheel skidding, research on electronics based seed metering mechanism in planters and seed drills has been done for precise placement of seeds during planting.

Further drawbacks of the mechanical metering devices are the bulkiness of the system and vibrations that are induced on the planter or seed drill as it travels through the field. The final drawback of the mechanically driven system is the lack of communication of seed placement between row units on an implement. On current metering designs, the system has control over only the seeding population, but not the actual timing and placement of the seed. This means a seed is dropping into the furrow at a constant rate, but the row unit cannot detect the time and place where a seed is being placed relative to its neighbouring row units. Therefore, electronically controlled seed singulation devices can address many of the inefficiencies experienced in a mechanically driven seed metering device and have the potential to increase productivity and yield rates dramatically.

Working principle and components of mechatronics sowing system

The mechatronics mechanism works on the principle that shaft encoder senses the forward speed and transmit signals in the digital code to the microcontroller. The microcontroller synchronizes the forward speed of operation into 1:1 transmission ratio with the metering mechanism plate. The microcontroller transmits signals to motor driver module and driver connected to electric motor which rotate seed plate of the metering mechanism (Fig. 1).

He *et al.,* (2017) designed a mechatronic system for four row planter consists of seed box, touch screen display, shaft encoder to measure travel speed, electric motors, seed meters, and power supply (Fig. 2). A twelve volt tractor battery provides power for the Mechatronics system. The value of travel speed is measured by an incremental encoder that is mounted on the shaft of a ground wheel. With the rotation of the ground wheel, the encoder outputs corresponding pulses from which the controller can calculate travel speed by measuring the number of pulses received within a given time. The drive motors are brushless DC motors, each with three Hall-effect sensors mounted in the back for measuring the positions of the U, V, and W rotors, which realizes current switching for the rotors. Simultaneously, the three Hall-effect sensors measure the motor speed in real time to achieve closed loop control. A touch screen display allows the entry of parameters such as seed spacing, wheel slip ratio, diameter of the ground wheel, and number of seed holes per disk, displays travel speed, and seed plate rotation speed, and sounds alarms to warn of system malfunction. The controller main functionality is to output a pulse signal with a given frequency and duty cycle to control seed plate rotation speed based on travel speed to achieve uniform seed spacing.

Trends of mechatronics in sowing

As one of the trends of development on automation and intelligence of agricultural machinery in the 21st century, all kinds of agricultural robots have been researched and developed to implement a number of agricultural production in many countries, such as picking, harvesting, weeding, pruning, planting, grafting, agricultural classification, etc. Application of electronics in agriculture has come with the technological advancement. The microcontroller or microprocessors for control of electronic circuitry are now economical and powerful tool with very low error margin as well as testing whether any machine operates in the right adjustment or not.

Not only the hardware but also open source user friendly software has been developed. This has encouraged researcher for specific electronics application in agriculture. The microcontroller can be used as per the need for actuation and sensing. The sensors are used by the researchers for seed placement for depth and distance control (Panning *et al.*, 2000; Lan *et al.*, 1999). Using electronics for metering mechanism may be one of the options to achieve accurate seed spacing with higher efficiency. Sensors can be used in precision planting if integrated with seed metering mechanism. A summary of mechatronics studies in seed sowing focusing on many different aspects is presented below in Table 1, 2, 3, 4 and 5.

Performance parameters related to precision planter

The sowing uniformity of seed distribution along the length of the row was analysed using the methods described by Kachman and Smith. Miss index (MI) is the percentage of seed spacings that are greater than 1.5 times the nominal seed spacing and indicates the percentage of missed seed locations or skips. Quality of feeding index(QFI) is the percentage of seed spacings that are more than half but no more than 1.5 times the nominal spacing and indicates the percentages of single seed drops. Precision index (PREC) is the coefficient of variation of the spacings (length) between the nearest seeds in a row that are classified as singles after omitting the outliers consisting of missing-seedings and multiples. The calculation formulas for MI, QFI and PREC (Gautam, 2017) are as follows:

$$QFI = \frac{n'}{N}$$

$$MI = \frac{n''}{N}$$

$$PREC = \frac{S}{\bar{x}}$$

$$MULT = \frac{n}{N}$$

Where,

S = $\sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \bar{x})^2}$ (standard deviation of seed spacings)

$$\bar{x} = \frac{1}{N}\sum_{i=1}^{N} x_i$$

x_i= is the nth seed spacing
N = Total number of seed spacings, and
n''= Number of spacings in the region greater than 1.5 times of the theoretical spacing
n' = Number of spacings between 0.5 times the theoretical spacing and 1.5 times of the theoretical spacing
n = Number of spacing's in the region less than or equal to 0.5 times of the theoretical spacing

Suggested upper limit of PREC index for single seed planter is 29% (Nejadi and Raoufat, 2013; Raoufat and Mahmoodieh, 2005). Planting performance indicators were evaluated by using the criteria provided in Table 6 (Aykas *et al.*, 2013; ISO 7256/1-1984(E) Standard, 1984; Önal *et al.*, 2012).

Table.1 Mechatronics in seed drill

S/N	Researcher Name	Seed	Research Topic	Electronic Components	Source	Address of Researcher	Journal Name
1.	M. Jafari, A. Hemmat and M. Sadeghi	Wheat	Development and Performance Assessment of a DC Electric Variable-Rate Controller for Use on Grain Drills.	DC motor, encoders(E50S-2500-3-2-24 and ISE-200-5V)), GPS receiver, pulse-with-modulation (PWM) DC motor controller, laptop, 12–24V supply , 12-step CMOS4040 IC, A 74LS138 IC, PID controller, MOSFET, 74LS373 IC	Jafari et al., (2010)	Department of Farm Machinery, College of Agriculture, Isfahan University of Technology, Isfahan 84156-83111, Iran. ahemmat@cc.iut.ac.ir	Computers and Electronics in Agriculture
2.	Caner Cuhac, ReinoVirrankoski, Petri Hanninen, Mohammed Elmusrati, HermanniHoopakka and HeikkiPalomaki	Rye, Wheat, Barley, Corn and Oat	Seed Flow Monitoring in Wireless Sensor Networks.	LED, Light Dependent Resistors (LDR), receiver UWASA Node, ultrasonic and microwave sensor, SURFbuttons, SPI bridge, LCD display, transmitter, battery	Cuhac et al., (2012)	University of Vaasa Department of Computer Science Communications and Systems Engineering Group P.O.Box 700, FI-65101 Vaasa, Finland	Workshop on Wireless Sensor Systems
3.	HifjurRaheman and Rajeev Kumar	Wheat and Ragi	An Embedded System for Detecting Seed Flow in the Delivery Tube of a Seed Drill	12 V DC battery, DC motor, potentiometer, DC motor driver, microcontroller (Arduinouno), IR sensor and buzzer	Raheman& Kumar, (2015)	Agricultural and Food Engineering Department, IIT, Kharagpur, India	Proceeding of International Conference on ACBEE
4.	S. Kamgar, F. Noei-Khodabadi and S.M. Shafaei	Wheat	Design, Development and Field Assessment of a Controlled Seed Metering Unit to be Used in Grain Drills for Direct Seeding of Wheat	digital encoder (Autonics E50S8-1000), variable-rate DCM (model: D12-8001-45W), 4x4 matrix keyboard Device, Atmega16 microcontroller, 16 x2 LCD, PATA cable, PID controller, direct current voltage transducer	Kamgar et al., (2015)	Department of Biosystems Engineering, College of Agriculture, Shiraz University, Shiraz 71441-65186, Iran. smshafaei@shirazu.ac.ir	Information Processing in Agriculture
5.	SørenKirkegaard Nielsen, Lars JuhlMunkholm, Mathieu Lamandé, Michael Nørremark, Gareth T.C. Edwards and Ole Green	Spring Barley	Seed Drill Depth Control System for Precision Seeding	Linear position sensors TX2, P43 ultrasonic height sensors, ultrasonic sensors, X20 controller, electrohydraulic 4/3 oil direction valve SV08-47B, GNSS BT-Q1000XT and pilot-controlled leak-proof	Nielsen et al., (2018)	Aarhus University, Faculty of Science and Technology, Department of Engineering, Denmark	Computers and Electronics in Agriculture
6.	Karan Singh, K. N. Agrawal and Anurag Kumar Dubey	Soyabean	Development of the Contoller based Seed cum Fertilizer Drill	Programmable PLC/PMW controller, inductive proximity sensor, AC motor, 24V DC motor, SMPS, encoder, USB, RS-232 and flash card	Singh et al., (2012)	ICAR-CIAE, Bhopal, India. ksingh@ciae.res.in	12th International Conference on IEEE.
7.	HadiKarimi, HosseinNavid and AsgharMahmoudi	Wheat, corn and pelleted tomato	Online laboratory evaluation of seeding-machine application by an acoustic technique	Microphone (VM-034CY), sound card (Intel® 82801 BA/BAM AC'97 Audio controller), MATLAB software	Karimi et al., (2015)	University of Tabriz, Faculty of Agriculture, Department of Agricultural Machinery. Tabriz, Iran hadiekarimi@gmail.com	Spanish Journal of Agricultural Research

Table.2 Mechatronics application in mechanical planter

S/N	Researcher Name	Seed	Research Topic	Electronic Components	Source	Address of Researcher	Journal Name
8.	D. E. Wilkins and D. H. Lenker	Lettuce	A microprocessor-controlled planter	8080Amicroprocessor, LED, phototransistor, power source and solenoid air valve	Wilkins and Lenker, (1981)	USDA SEA-AR, Columbia Plateau Conservation Research Centre, Pendleton(US)	Transactions of the ASAE
9.	P. R.Shinde, A. B. Lende, S.V. Rane, S. A.Nawale, M. S. Patwardhan, and L. V.Gharate	Groundnut	Development and Functional Test of Electronic Metering Mechanism for Bullock Drawn JyotiMulticrop Planter.	Opto-isolator sensors, microcontroller (ATMEL89), BC547 and SL100 transistors, 2x16 LCD, solenoid switches, 12Vbattery and keyboard.	Shinde *et al.*, (2009)	Department of Farm Machinery and Power, Dr. A. S. College of Agricultural Engineering, Mahatma PhuleKrishiVidyapeeth, Rahuri - 413 722, India.	International Journal of Agriculture Environment and Biotechnology
10.	Lianming Xia, Xiangyou Wang, DuanyangGeng and Qingfeng Zhang	Maize and wheat	Performance Monitoring System for Precision Planter Based onMSP430-CT171	IR LED, phototransistor, photoelectric sensor, LM339, microcontroller (MSP430-CT171), display module (LMC240128ZK), LCD, Bluetooth module, FS-BT485A serial adapter, RS232, Buzzer, Stepper motor, motor driver, keyboard circuit and power driver	Xia *et al.*, (2010)	School of Agricultural and Food Engineering, Shandong University of Technology Zibo, Shandong, China	International Conference on Computer and Computing Technologies in Agriculture
11.	M. Anantachara, Prasanna G.V. Kumar and T. Guruswamya	Peanut	NN Prediction of Performance Parameters of an Inclined Plate Seed Metering Device and Its Reverse Mapping for the Determination of Optimum Design and Operational Parameters	Opto-electronic seed counter, electric motor , ANN models	Anantachara *et al.*, (2010)	Department of Farm Machinery, College of Agricultural Engineering, University of Agricultural Sciences, Raichur 584101, Karnataka, India gvpk@yahoo.com	Computers and Electronics in Agriculture
12.	O. Hajahmed, E. Tola, K. A. Al-Gaadi and A. F. Kheiralla	Chickpeas seeds	Development of an Opto-Electronic Monitoring System for Crop Planter Seed Metering Unit	AC motor (220 Volt, 0.4 kW), Digital Fiber Sensor (E3X-DA-S), rotary encoder (E6B2- CWZ6C), microcontroller (Atmel ATMega16L)	Hajahmed et al., (2011)	Precision Agriculture Research Chair (PARC), College of Food and Agricultural Sciences, King Saud University. P.O. Box 2460, Riyadh 11451, Saudi Arabia	Middle-East Journal of Scientific Research
13.	T. P. Singh and D. M. Mane	Okra	Development and Laboratory Performance of an Electronically Controlled Metering Mechanism for Okra Seed	Proximity sensor, pulse generator, BCD counter(IC 4510), Timer (IC 4093), Relay unit, DC motor, 12 V tractor battery, screw control knob.	Singh and Mane, (2011)	Farm machinery and Power Engineering College of Technology G. B. Pant University of Agriculture and Technology Pantnagar-263145, Uttarakhand INDIA. tpsingh_62@yahoo.co.in	Agricultural Mechanization in Asia, Africa, and Latin America
14.	H. Navid, S. Ebrahimian, H. R. Gassemzadeh and M. J. Mousavinia	Pelleted tomato seeds	Laboratory Evaluation of Seed Metering Device using Image Processing Method	Digital camera (Nikon, D70), USB port and MATLAB software	Navid et al., (2011)	Department of Agricultural Machinery Engineering, University of Tabriz, Tabriz, I.R. Iran navid@tabrizu.ac.ir	Australian Journal of Agricultural Engineering
15.	TejminderKaur and Dilip Kumar	Wheat	Design and Development of Calibration Unit for Precision Planter.	Frame light barrier sensor, Proximity sensor (gear tooth sensor), SMU, 1 hp AC motor, Yaskawa J1000 AC drive, RS232 and USB communication	Kaur& Kumar, (2013)	Centre for Development of Advanced Computing(C-DAC), Mohali, India	International Journal of Computer Science, Engineering and Applications

16.	Du Ruicheng, Gong Bingcai, Liu Ningning, Wang Chenchen, Yang Zidong and Ma Mingjian	Corn	Design and Experiment on Intelligent Fuzzy Monitoring System for Corn Planters	On-board computers, GPS receivers, digital cameras, tilt sensor, USB-CAN interface module, displacement sensors, electronically controlled stepless spacing regulator, CAN bus analog input module, CAN bus digital input and output modules, CAN bus pulse counting module, seed tank sensor, fertilizer tank sensor, seeding orifice sensor and gear speed sensor	Ruicheng et al., (2013)	School of Agriculture and Food Engineering, Shandong University of Technology, Zibo 255049, Shandong, China	International Journal of Agricultural and Biological Engineering
17.	JavadTaghinezhad, Reza Alimardani and Ali Jafari	Sugarcane	Design a Capacitive Sensor for Rapid Monitoring of Seed Rate of Sugarcane Planter	Rectangular parallel plate capacitor, electronic circuitry, microcontroller, and display unit	Taghinezhad et al., (2013)	Department of Agricultural Machinery Engineering, Faculty of Agricultural Engineering and Technology University of Tehran, Iran	Agricultural Engineering International: CIGR Journal
18.	Margarita Velandia, Michael Buschermohle , James A. Larson , Nathanael M. Thompson , Brandon Michael Jernigan	Corn, soybean and cotton	The economics of Automatic Section Control Technology for Planters: A Case Study of Middle and West Tennessee Farms	GPS receiver (Trimble EZ-Guide 500 system), GPS antenna (Trimble AgGPS 25 antenna), Intercom RTK Bridge cellular modem, netbook computer, data logger and switches	Velandia et al., (2013)	Department of Agricultural and Resource Economics, The University of Tennessee, Knoxville, TN, United States	Computers and Electronics in Agriculture
19.	ZhaiJianbo, Xia Junfang, Zhou Yong and Zhang Shun	Soybean	Design and Experimental Study of the Control System for Precision Seed-Metering Device	Hall sensor, AT89S51 single chip microcomputer, Motor control module, 57H76-03 stepper motor and adjustable speed motor	Jianbo et al., (2014)	College of Engineering, Huazhong Agricultural University, Wuhan430070, Hubei Province, China	IJABE
20.	V. V. Aware and S. V. Aware	Cowpea	Development of Microprocessor based Electronic Metering Mechanism for Seed–an Approach	Microcontroller (AT89C51 IC), inverter , D.C. motor, operational amplifier (LM741), 2 X 16 LCD Display, tactile switches, 12 MHz crystal oscillator, Capacitors, Diodes, opto- electric sensor, 230 V, 50 Hz A.C supply, Transformer	Aware& Aware, (2014)	Department of Farm Machinery and Power, College of Agricultural Engineering and Technology, Dr. B.S. Konkan Krishi Vidyapeeth, Dapoli, RATNAGIRI (M.S.), INDIA	Engineering and Technology in India
21.	CristianIacomi and Octavian Popescu	Pelleted lettuce and carrot	A New Concept for Seed Precision Planting	Linear solenoid actuator, Optoelectronic sensor (IR LED, phototransistor) and electronic switch	Iacomi&Popescu, (2015)	University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Marasti Blvd, 011464, Bucarest-1, Romania	Agriculture and agricultural science procedia
22.	Niu Kang, Fang Xianfa, Liu Yangchun, LüChengxu and Yuan Yanwei	Potato	Optimized Design and Performance Evaluation of an Electric Cup-Chain Potato Metering Device	Microcontroller (PIC18F2580), motor control circuit, GPS, D/A translate box , servo motor, differential GPS, RS232 serial port, PID control algorithm, servo motor (SGMJV-04ADE6S), servo driver (SGDV-2R8A01B002000) analysis software DPS v7.05 and Matlab R2012A	Kang *et al.*, (2017)	College of Engineering, China Agricultural University, Beijing 100083, China yyw215@163.com	International Journal of Agricultural and Biological Engineering
23.	ShankhaKoley, Y.C. Bhatt, Gajendra Singh, Sunil Joshi and H. K. Jain	Ground nut	Development of Electronic Metering Mechanism for Precision Planting of Seeds	Proximity sensor, microcontroller (AT89C51), motor driver (L293D), DC motor, potentiometer (150 W) and power source	Koley *et al.*, (2017)	Indian Institute of Technology, Kharagpur, India	International Journal of Current Microbiology and Applied Sciences

Table.3 Mechatronics in Pneumatic Planter

S/N	Researcher Name	Seed	Research Topic	Electronic Components	Source	Address of Researcher	Journal Name
24.	Y. Lan, M. F. Kocher and J. A. Smith	Sugar beet and pelleted chicory	Opto-electronic Sensor System for Laboratory Measurement of Planter Seed Spacing with Small Seeds	NIR LEDs (EG and G VACTEC GaAs VTE3322LA), phototransistors (EG and G VACTEC NPN VTT3323LA), digital input/output (I/O) board, opto-electronic sensor, Hall-effect switch ,3)58 MHz clock, data-acquisition program	Lan *et al.*, (1999)	Department of Biological Systems Engineering, University of Nebraska, Lincoln, NE 68583, USA	Journal of Agricultural Engineering Research
25.	ZelihaBereketBarut and KadirYiğit	Corn	Design of Electronic-Based Measurement System for Seed Spacing Measurement in Precision Planters	Microcontroller (AT89S8252), fiber-optic sensor amplifier. 2 fiber-optic sensors and 2 mutual fiber-optic cables, analog-digital converter, electrical motor.	Barut&Yiğit, (2008)	Çukurova University, Faculty of Agriculture, Department of Agricultural Machinery, 01330, Adana, Turkey	10th International Congress on Mechanization and Energy in Agriculture
26.	Okan ÖNAL and İsmet ÖNAL	Hybrid maize and cotton	Development of a Computerized Measurement System for In-Row Seed Spacing Accuracy	CMS hardware, laser pointer, notebook computer, optical mouse (Microsoft Optical Mouse 3000) ,USB cable extension, Light meter (Lutron model Lx-1108) and CMS software	Önal & Önal, (2009)	DokuzEylül University, Department of Civil Engineering, Kaynaklar Yerleşkesi, Buca, İzmir – TURKEY. okan.onal@deu.edu.tr	Turkish Journal of Agriculture and Forestry
27.	SaadatKamgar and Mohammad J. Eslami		Design, Development and Evaluation of a Mechatronic Transmission System for Upgrading Performance of a Row Crop Planter	45W DC motor, tractor battery (12V&75Ah), microcontroller, MOSFET, potentiometer, rotary shaft encoder (E50S8-1000), 4×4 matrix keyboard and 2×16LCD	Kamgar&Eslami, (2012)	Agricultural Engineering Department, Shiraz University, Shiraz, Iran. kamgar@shirazu.ac.ir	American Society of Agricultural and Biological Engineers
28.	SaadatKamgar, Mohammad JavadEslami and Mohammad Mehdi Maharlouie		Design, Development and Evaluation of a Mechatronic Transmission System to Improve the Performance of a Conventional Row Crop Planter	45W DC motor, tractor battery (12V&75Ah), microcontroller, MOSFET, potentiometer, rotary shaft encoder (E50S8-1000), 4×4 matrix keyboard and 2×16LCD	Kamgar et al., (2013)	Agricultural Engineering Department, Shiraz University, Shiraz, Iran. kamgar@shirazu.ac.ir	International Journal of Agronomy and Plant Production
29.	Qi Jiangtao, JiaHonglei, Li Yang, Yu Haibo, Liu Xinhui, LanYubin, FengXianzhen and Yang Yongxi	Corn	Design and Test of Fault Monitoring System for Corn Precision Planter	Capacitive sensors (TAP-30D40N1-D3 model), Display module (JM160128BLCD), matrix keyboard, single-chip microcomputer (STC12C5A60S2), alarm module, input module, count chip (74LS590), encoder (PHB8-3600-G05L) and 8255A chip.	Jiangtao et al., (2015)	Key Laboratory of Bionic Engineering (Ministry of Education), Jilin University, Changchun 130022, China	International Journal of Agricultural and Biological Engineering
30.	Yang Li, He Xiantao, Cui Tao, Zhang Dongxing, Shi Song, Zhang Rui and Wang Mantao	Corn	Development of Mechatronic Driving System for Seed Meters Equipped on Conventional Precision Corn Planter	Two-phase hybrid stepper motor (57HBP76AL4-TF0), tractor battery, driver module (2HD403), rotary shaft encoder (TRD-2T500BF), touchscreen (MT4414T), RS485 and microcontroller (STM32F103VCT6)	Li et al., (2015)	College of Engineering, China Agricultural University, Beijing 100083, China zhangdx@cau.edu.cn	International Journal of Agricultural and Biological Engineering
31.	HabibKocabiyik, Anil Cay, Bilal Karaaslan, Sahin May and M. Khurelbaatar	Corn	Electro-mechanic Control System for Pneumatic Precision Corn Planters	ESC (electronic speed controller), driver module, DC electric motors, encoders, cables connectors ,PWM and PID techniques	Kocabiyik et al., (2016)	CanakkaleOnsekiz Mart University, Faculty of Agriculture, Department of Agricultural Machinery and Technologies Engineering, 17020, Canakkale, Turkey.	International Conference on Machine Control and Guidance
32.	Devin L. Mangus,	Corn	Development of High-Speed	Borsch Terminal ME controller, radar	Mangus *et al.*,	Biological and Agricultural	Computers and

	Ajay Sharda, Daniel Flippo, Ryan Strasser and Terry Griffin		Camera Hardware and Software Package to Evaluate Real-Time Electric Seed Meter Accuracy of a Variable Rate Planter	speed sensors, control laptop computer, Compact Rio (DAS), bore encoders, controller display, seed tube Sensors and high-speed camera	(2017)	Engineering, Kansas State University, 1016 Seaton Hall, Manhattan, KS 66506, United States	Electronics in Agriculture
33.	X. He, T. Cui, D. Zhang, J. Wei, M. Wang, Y. Yu, Q. Liu, B. Yan, D. Zhao and L. Yang	Corn	Development of an Electric-Driven Control System for a Precision Planter Based on a Closed-Loop PID Algorithm	Display (MT4414T), incremental encoder (TRD-2T500BF), four drive motors, 12V tractor battery, Hall-effect sensors, Optical Coupler (PC357), RS232 Transceiver (MAX232), Main Controller (STM32F103VCT6), Auxiliary Controller (STM32F103RBT6) and power MOSFET	He et al., (2017)	College of Engineering, China Agricultural University, Beijing 100083, China. yl_hb68@126.com	Computers and Electronics in Agriculture
34.	YongliangHao, Tao Cui, Ganesh Bora, Dongxing Zhang, Jiantao Wei, Xiantao He, Mantao Wang and Li Yang	Corn	Development of an Instrument to Measure Planter Seed Meter Performance	Servo motor and gearbox, motor driver, seed sensor, PLC controller (CPU504EX) ,tablet computer and printer (J625DW)	Hao et al., (2017)	College of Engineering, China Agricultural University, Beijing 100083, China. yangli@cau.edu.cn	Applied Engineering in Agriculture
35.	Anil Cay, HabibKocabiyik and Sahin May	Corn	Development of an electro-mechanic control system for seed-metering unit of single seed corn planters Part I: Design and laboratory simulation	Control panel, processor, electronic speed controller, driver module, brushless DC electric motors and other Supplementary elements such as encoders, cables and connectors.	Cay et al., (2018)	Department of Agricultural Machinery and Technologies Engineering, Faculty of Agriculture, CanakkaleOnsekiz Mart University, Canakkale, Turkey	Computers and Electronics in Agriculture
36.	Anil Cay, HabibKocabiyik and Sahin May	Corn	Development of an Electro-Mechanic Control System for Seed-Metering Unit of Single Seed Corn Planters Part II: Field Performance	Control panel, processor, electronic speed controller, driver module, brushless DC electric motors and other Supplementary elements such as encoders, cables and connectors	Cay et al., (2018)	Department of Agricultural Machinery and Technologies Engineering, Faculty of Agriculture, CanakkaleOnsekiz Mart University, Canakkale, Turkey	Computers and Electronics in Agriculture

Table.4 Mechatronics in Magnetic Planter and Trans-Planter

S/N	Researcher Name	Seed	Research Topic	Electronic Components	Source	Address of Researcher	Journal Name
37.	Yan Xiaoyue, Hu Jianping, Ma Jun and Wang Xun	Rape seeds	Design of a Control System for Magnetic Plate-type Precision Seeding Production Line Based on PLC and MCU.	Permanent magnetic plugs, AC motors(90YYJ (T) 120-30), controller(ES / EX series Delta DVP-40ES PLC), step Motor (110BF-003 and 85STH118), step motor driver (BQH-300Y and WZM-2H057M), LJD-51-XB +MCU, photoelectric sensors (SICK GL6-N1111), capacitive proximity sensors (SND05-N) and controller (DVP-40ES PLC)	Xiaoyue et al., (2013)	Laboratory of Modern Agricultural Equipment and Technology, Ministry of Education and Jiangsu Province, Jiangsu University, Zhenjiang, 212013, China	Electrical and Electronic Engineering Journal
38.	Liguo Wei, Xiaochao Zhang, QuanJia, and Yangchun Liu	Rice	Automatic Navigation System Research for PZ60 Rice Planter	RTK-GNSS receiver, electro-hydraulic proportional valve, attitude transducer, fuzzy control unit and engine power (8.3 kW)	Wei et al., (2014)	Chinese Academy of Agriculture Mechanization Sciences, Beijing 100083, China weilg78@126.com	International Conference on CCTA
39.	B. M. Nandede and H. Raheman	Pot seedlings of tomato brinjal and chilli	Digital Seedling Counter for Detection of Seedling Flow and Spacing in Vegetable Trans planter: A Low Cost Solution	Microcontroller (PIC16F877A), LCD display and RS232 port, power supply unit (12 V batteries or 220 VAC supply), transformer, rectifier diodes, regulator IC, capacitors, light source, optical sensor, comparator and LED.	Nandede&Rahman, (2016)	ICAR-central Institute of Agricultural Engineering, Bhopal, MP (India)	International Journal of Engineering Research and Management Technology

Table.5 Seed Sowing Robot

S/N	Researcher Name	Seed	Research Topic	Electronic Components	Source	Address of Researcher	Journal Name
40.	M. Priyadarshini and L. Sheela		Command based Self-Guided Digging and Seed Sowing Rover	DC motor, Ultrasonic Radar sensor, sowing control sensor, relay driver circuit, Wireless controller, PC, Bluetooth module,vBattery package, Arduino mega2560 microcontroller and LCD module	Priyadarshini&Sheela, (2015)	Dept of EEE, Embedded System Technologies Regional office:Anna University Tirunelveli, India	International Conference on Engineering Trends and Science and Humanities
41.	Swati D. Sambare and S. S. Belsare		Use of robotics technology for seed sowing in Agriculture	Keyboard, Zigbee module, PC, IR sensor, L293D driver module, DC Motor, stepper motor , UNL2803, LCD, LPC2148microcotrolle, MAC layers	Sambare&Belsare, (2015)	Dept. of Electronics, BVDUCOEP, Pune, India sambare.swati@gmail.com	IJSRM
42.	Lin Haibo, Dong Shuliang, Liu Zunmin and Yi Chuijie	Wheat	Study and Experiment on a Wheat Precision Seeding Robot	Drive motor, Steer motor, Seeding motor, Motor driver, Motor controller, Controller, PC, Lead-acid Batteries, sensor for pressure and speed	Haibo et al., (2015)	College of Mechanical Engineering, Qingdao Technological University, Qingdao 266520, China	Journal of Robotics
43.	Neha S. Naik, Virendra. V. Shete and Shruti R. Danve	Cotton, Maize, Soybean and Wheat	Precision Agriculture Robot for Seeding Function	Power supply(9 and 12 V DC), input switches, IR sensors, relays, 16x2 LCD display, DC motors, motor driver (L293D IC), ARM7 board, microcontroller (LPC2148)	Naik et al., (2016)	Department of E and TC, MITCOE, Pune, India nhnk27@gmail.com	International Conference on IEEE
44.	Kiran AS and BabanParisaDathwade		Design and Fabrication of Automatic Seed Sowing Machine with Variable Pitch	Microcontroller, DC Gear Motor, rotary encoder, Battery, Keypad	Kiran&Dathwade, (2016)	Department of Mechanical Engineering, BCE, Shravanabelagola, India kiranas.april92@gmail.com	European Journal of Advances in Engineering and Technology
45.	Palepu V. Santhi, NelloreKapileswar, Vijay K. R. Chenchela and Venkata Siva Prasad. CH		Sensor and vision based autonomous AGRIBOT for sowing seeds	Controller (Arduino), Ultrasonic and IR sensors, vision sensor, power supply, PC	Santhi et al., (2017)	Department of Electrical, Electronic and Computer Engineering, University of Pretoria, South Africa	ICECDS
46.	AnujaMohalkar,PritiMohite, ShubhangiNagare, and SampadaTavse		Automatic Seed Sowing Machine using Solar Panel	Microcontroller (PIC16F877A), Keypad, LCD, DC Motor Driver (L293D), IR Sensor, DC motors, 12V battery, amplifier, buzzer, keypad and solar panel	Mohalkar et al., 2017)	Department of E and TC Engineering, MarathwadaMitraMandal's College of Engineering, Pune, India anujamohalkar@gmail.com	International Journal of Innovations in Engineering Research and Technology
47.	RohanChauhan		Electronic Demarcation Technique for Robotic Precision Planter	Microcontroller(Arduino Mega), DOF IMU, rotary encoder, stepper motors, sensors, raspberry Pi3, Camera, motor board, battery, power bank, DC-DC converter and Ubuntu Mate	Chauhan, (2017)	Kalinga Institute of Industrial Technology, School of Computer Engineering, Bhubaneswar, Odisha, India.	Journal of Engineering and Applied Sciences
48.	T. V. Pavan, R. Suresh, K. R. Prakash, and C. Mallikarjuna	Green gram	Design and Development of Agribot for Seeding	12V DC geared motors, Arduino Uno board, Atmega328 microcontroller, motor driver (L298), Voltage regulator785, lead acid battery, Ultrasonic sensor,	Pavan et al., (2017)	Dept. Of Industrial Automation Engineering, VTU PG Studies, Mysuru, Karnataka, India	International Research Journal of Engineering and Technology
49.	ShraddhaMuley and Warsha S. Kandlikar	Soybean, Jowar, Wheat and Peanut	Robotic Vehicle for Seed Planting and Weeding Applications	ultrasonic sensor, keypad, LDR, LED, DC motors, motor driver, Arduino Due Board, microcontroller (Atmel SAM3X8E ARM Cortex-M3 CPU), SDA and SCL pins, Due and AVR-based boards, Ultrasonic ranging module HC - SR04 and L293D IC	Muley&Kandlikar, (2017)	Department of Electronics Design and Technology, National Institute of Electronics and Information Technology, Dr. B.A.M. University Campus, Aurangabad India	International Journal for Innovative Research in Science and Technolog y
50.	Nikita Chame, MamtaJadhav, Priyanka Tele and Snehal P. Hon		Design and Implementation of Automatic Seed Sowing Robot	12V battery, voltage regulator, PID controller, LDR sensor, IR sensor, DC motors driver IC L293D, DC motors, ADC(Atmega328p), Servo motor, Pulse Width Modulation	Chame et al., (2018)	Department of Electronics and Telecommunication, PES MCOE, Pune, India	International Journal of Research in Engineering, Science and Management

Table.6 Limit values of performance criteria for precision seeding (Cay *et al*., 2018)

QFI (%)	MI (%)	MULT (%)	Classification
>98.6	<0.7	<0.7	Very good
>90.4–98.6	≥0.7 to<4.8	≥0.7 to<4.8	Good
≥82.3 to ≤90.4	≥04.8 to<7.7	≥04.8 to<10	Moderate
<82.3	>7.7	>10	Insufficient

Table.7 Results Obtained in Different Study with Mechatronics

Source	Speed (Kmh^{-1})	Results			
		QFI (%)	**MULT (%)**	**MI (%)**	**PREC (%)**
Cay *et al*., (2018)	5 – 10	2.91–95.36	0–1.73	4.45–97.09	8.79–22.14
Mangus *et al*., (2017)	2.4 -16.1	98.45	0.2	0.8	---
Cay *et al*., (2018)	5 – 10	90.63	0.94	8.44	17.63
Taghinezhad *et al*., (2013)	0.9 – 3.6	89.72 - 93.43	2.52 - 7.23	2.81 - 7.26	---
Jianbo *et al*., (2014)	3.6–7.2	85.83 - 95	0 - 3.34	5 - 10.83	---
Jiangtao *et al*., (2015)	4.00	89.4 - 91.46	2.44 -3.86 %	5.28 - 9.11	---
Xiaoyue *et al*., (2013)	0.52rad/s.	90.28	4.69	5.04	---
Singh and Mane, (2011)	1 - 3.4	100	0	0	1.84 - 7.34
Önal&Önal, (2009)	1.8 - 7.2	91.30	2.90	5.80	---
He *et al*., (2017)	8.6 - 13	96.9 - 98.81	---	1.19 - 3.1	14.38 - 16.04
Hao *et al*., (2017)	3 - 12	95.1 - 98.1	0.2 - 0.7	1 - 4.2	---
Kocabiyik *et al*., (2016)	5 - 10	31.73 - 97.18	0 - 0.82	2.45 - 69.27	9.57 - 14.07
Li *et al*., (2015)	9 - 12	89.93 - 94.23	---	2.49 - 5.03	17.85 - 18.80

Fig.1 Principle of mechatronics metering mechanism (Jiangtao *et al*., 2015)

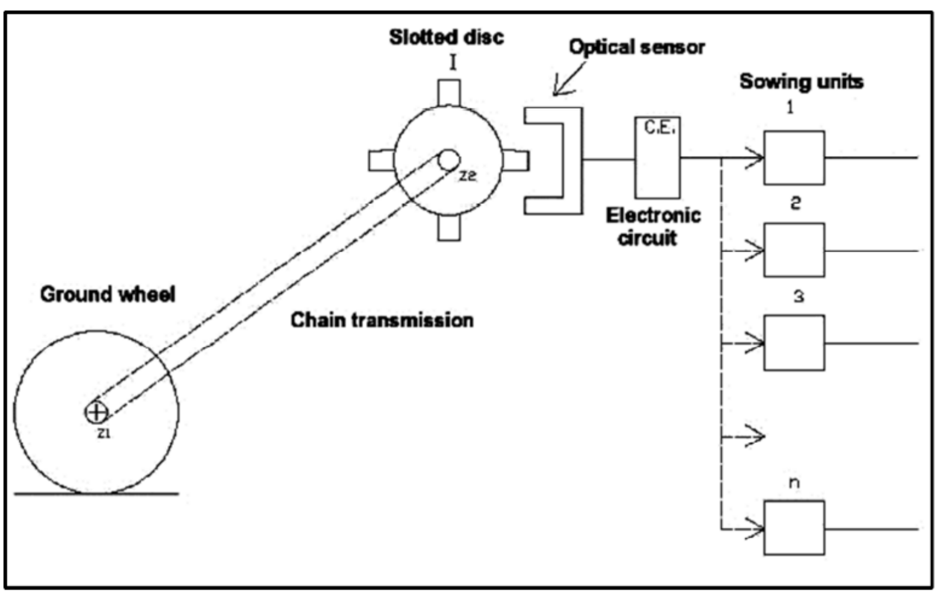
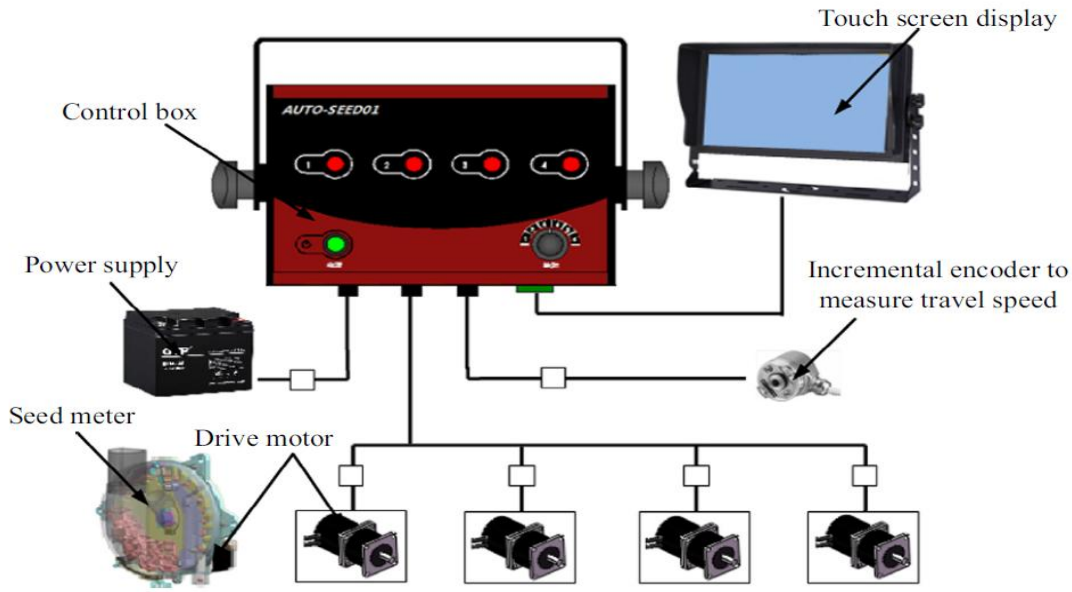


Fig.2 Components of the mechatronics drive system (He *et al*., 2017)



Different studies' result

It was observed that as the working speed increased, quality of feed index (QFI) of the seed-metering device dropped gradually with increased miss index (MI) and precision index (PREC) as well as deviation from the average seeds spacing became greater. The multiple index (MULT) decreases with increase in speed. The studies were indicated that precision planter equipped with mechatronics system observed good seeding uniformity among all seeding technologies with QFI, MI, MULT and PREC in range of 90-98, 0-11, 0-7 and 1-22 per cent, respectively under travel speed of 1 to 16 km h^{-1} (Table 7). Thus, mechatronics metering mechanism may be one of the options to achieve accurate seed spacing with higher efficiency in planting/seeding and capable to reduce the effect of higher speed of seeding.

It was observed that mechatronics driving system when attached with pneumatic plantercan reduce the effect of forward speed on planting accuracy effectively such as 4-8% increase in QFI and 4-7%decrease in MI.

Mechatronics system solves the problems of existing precision planters like as ground wheel skidding.

Possibility of getting more transmission ratio by changing the pulse width modulation like as variable rate technology.

Good seeding uniformity and high productivity obtained because lowering precision index value of precision index up to 15%.

Agribot gives near about 92% accuracy regarding placement of different type of seeds and it can much more accurate in future.

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