

Application of Artificial Intelligence and IoT technologies in agriculture and animal farming

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IoT smart farming solutions are a system designed for automating the irrigation system and monitoring the agricultural field with the aid of sensors (light, humidity, temperature, soil moisture, crop health, etc.). IoT technologies are enabling the farmers to manage their agriculture and animal farms more effectively and precisely which was not practically possible earlier. These technologies provide large qualitative datasets which can be used for finding hidden patterns and developing decision support systems. Sensing devices have proven their utility in monitoring agriculture and studying the behavior of animals which was otherwise difficult in manual system. The integration of these technologies into 'smart' husbandry support systems will ensure optimum wellbeing for dairy animals and thereby maximise farm profitability.

Keywords: Artificial intelligence, Farming, Internet of things

INTERNET of Things (IoT) refers to a system of interrelated computing devices, mechanical or digital machines and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction. Engineering advances and synergy of electronic, communication and computer engineering have led to development of low cost devices, also known as IoT, integrated with sensing, processing and communication capabilities. IoT devices provide real time data required for management of agriculture and dairy animals. These devices are capable of automatically sensing and collecting data continuously on various parameters such as temperature, moisture, climate, physiological parameters, production measures and behavioral traits. Such huge stream of data (qualitative and quantitative) processed with the help of artificial intelligence (AI) techniques can potentially help to develop a better decision support system. Such a smart system could also provide facility to the farmers

to monitor their field conditions live from anywhere and make appropriate decision based on the data, i.e. if the soil moisture level decreases, the farmer can irrigate the field remotely with the help of actuators. Therefore, smart farming is very efficient as compared to the conventional approach. Similarly, IoT can be used in dairy farms for identification of animals, tracking, heat detection, monitoring health and comfort level of animals, automation of milking process, segregation of animals based on health and production, fertility, nutrition, welfare, etc.

IoT Technologies

IoT devices are foundation of precision agriculture and animal farming. Various technologies for developing the IoT systems are as follows:

Sensor nodes: These nodes have the capacity to detect a range of biomolecular, chemical, optical, thermal, electrical, radiation and biological metrics. Different types of sensor nodes are available in the market, a few of them are as

mentioned below:

- Accelerometers
- Barometric pressure sensors
- Light sensors
- GPS modules
- Temperature sensors
- Humidity sensors
- Acoustic sensors
- Magnetic RPM sensors
- Magnetometers
- Solar radiation sensors
- Soil moisture sensors
- Soil temperature sensors
- Wind speed sensors
- Rainfall meters
- Seismic sensors
- Load sensors
- pH sensors

Controlling software: Controller software tools are widely used in IoT-based devices to automate the activities such as automatic switch to power on or off devices, opening or closing gates, and driving tractor remotely controlled via a controller, etc. In the precision agriculture/animal farming and IoT,

the controlling software provides capacity to control more than a dozen equipment/units simultaneously.

Connectivity protocols: Most of the network protocols work efficiently on short ranges (ZigBee or Wi-Fi), but long-range ones are most beneficial for precision agriculture. The most widely used connectivity protocols used by IoT in farming are cellular connection, LoRaWAN and LPWAN.

Location monitoring tools: Satellites are widely used to estimate the amount of water in the soil, crop biomass, and many other metrics. The data collected by connected GPS satellites or a location monitoring solution is then used by crop insurance companies, government, scientists, policymakers, and commodity bodies.

Backend analytical software: Data collected through IoT devices is processed at the backend using AI techniques to support the farmer/policy makers for improved decision making.

IoT solutions for Agriculture

IoT applications in agriculture have brought many benefits such as better access to farm records, plant disease forecasting, better crop protection, irrigation management, reduced wastage of resources and identification of patterns and trends, etc. These technologies have enabled the farmers in collecting more precise information on various parameters of agriculture, improving the quality of decision making and higher return on investment (RoI). A large number of applications of IoT have been found in the literature. These IoT solutions and applications can be grouped as follows:

Crop monitoring devices: These are used for monitoring crop health, pest control, nutrient requirement, disease control, spray of fertilizers, biochemical and physical properties. For e.g. a company called Blue River Technology has developed a real-time autonomous “see and spray” robot for applying fertilizers in the field. The robotics platform uses computer vision to recognize plants, and sprays herbicide on weeds and fertilizer on crops. Another

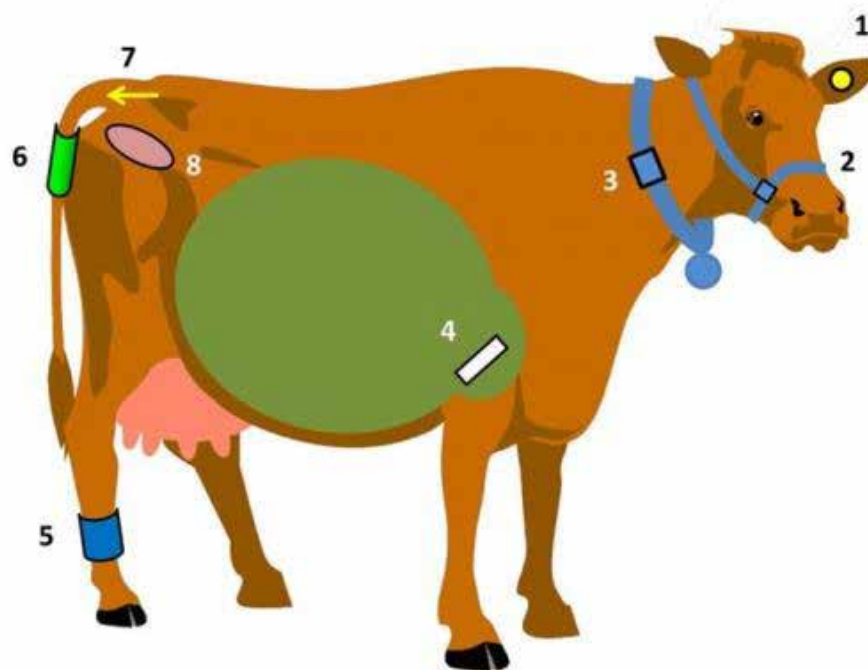
application, Farm Beats developed by Microsoft helps the farmers to increase farm productivity. Real-time data on parameters that may affect the growth of crops during cultivation processes, including wind speed, wind direction, soil moisture and temperature, CO₂, atmospheric pressure, as well as rain and light exposure is processed by machine learning algorithms at backend with predictive features. Similarly solutions are being developed to identify pest and disease at an early stage with the help of images.

Climate control: Weather stations help farmers to track and predict weather conditions of an area. After having collected insights from the environment, connected devices send the data to cloud-based storage. Farm managers can then use the information for climate mapping and crop selection. For e.g. aWhere Inc. uses satellite image data of the farms based on agronomic and climatic data such as temperature, precipitation, wind speed and solar radiation for decision making using machine learning techniques to predict weather, crop sustainability and the occurrence of diseases and pests.

Harvesting: Harvesting of crops at an appropriate time is an important factor for maximizing profit. Harvest CROO Robotics Company focused on revolutionizing the agriculture industry with automation. It has developed a robot technology to help the farmers in picking and packing of strawberry. Another company Abundant Robotics is developing a robot for apple picking.

Irrigation management: In the farmer’s field, careful and efficient management of water is required. By adopting centralized command-and-control tools, it can be precisely informed when to irrigate a given field. As a result, crops are preserved in a better state and water is also saved. CropX an ag-analytics company has developed cloud based software solutions integrated with wireless sensors, and offers mapping and optimal irrigation planning service to farmers through a mobile application.

Greenhouse automation: Many activities and processes in the greenhouse can be fully automated through IoT. For instance, humidity, temperature and lighting control can be automated. Even soil or nutrient



Body locations for mounting sensors for data collection in a cow are: (1) ear tag, (2) halter, (3) neck collar with counterweight, (4) reticulo-rumen bolus (in reticulum), (5) rear leg pedometer, (6) upper tail ring, (7) tail head inject, and (8) vaginal bolus. (Source: [Caja C, Castro-Costa A and Knight CH. 2016. Engineering to support well-being of dairy animals. *Journal of Dairy Research* : 83 136-147])

solution administration within the greenhouse can be managed without human supervision. For e.g. Motorleaf is enabling greenhouse farmers to more accurately forecast the future harvest by recording indoor growth data through sensors and processing by AI techniques.

IoT solutions for Dairy Animals

A large number of smart sensing devices coupled with analytical models and communication capabilities are commercially available to monitor activities and

performance of animals. These devices can be categorized as wearable and non-wearable devices. The wearable devices attached or mounted on the animals at different locations are connected to RF networks or internet. These devices are commonly used in dairy herds to monitor animal activities such as what the cow is doing and provides data for early detection of health or behavioral problems.

Most commercially available reproductive management technologies (e.g. oestrous

mating, calving) are based on activity recording using tri-axial accelerometers (Table 1). They are offered to wear as an ear tag, nose halter, neck collar or leg (preferably rear) pedometer. MooMonitor is a special device which uses pressure sensors for detecting the standing behaviour of dairy cows during oestrous. Simpler devices for heat and mating activity detection use RFID (radio frequency identification) transceivers attached to a harness for bulls and recognize cows (Celotor). Cows are identified

Table 1. Currently available wearable sensing technologies for monitoring the wellbeing of dairy animals

Objective	Manufacturer	Type & features	Technology used	Reference link
Activity behaviour (oestrous, feeding and health signs detection)	SensOor, CowManager	Ear: activity, feeding, health	RF, 3-axial accelerometer	http://www.cowmanager.com/enus/
	Cow Alert, IceRobotics	Leg: activity, oestrous, health	RF, 3-axial accelerometer	http://www.icerobotics.com/products/
	CowScout	Neck or leg: activity, eating time, oestrous	RF, 3-axial accelerometer	http://www.gea.com/global/en/products/activity-detectioncowscout.jsp
	Silent Herdsman Afimilk	Neck or leg: activity, oestrous, rumination	RF, 3-axial accelerometer	http://www.afimilk.com/products/cow-monitoring
	MooMonitor,	Neck: activity, oestrous, health	RF, 3-axial accelerometer,	http://www.dairymaster.com/heat-detection/
	HeatPhone, Medria	Neck: oestrous, health	RF, 3-axial accelerometer	http://www.medria.fr/en_GB/produits/heatphone.html
	HeatWath II, CowChips	Tailhead: oestrous	RF, pressure	http://www.cowchips.net/index.html
	Heatime, EFS (Westmeath, IE)	Neck: activity, oestrous, health	RF, 3-axial accelerometer	http://www.efsltd.ie/
	HeatSeeker, BouMatic	Leg: activity, intake, oestrous, lameness	RF, 3-axial accelerometer	http://www.boumatic.com/us-en/products/heatseeker1
Mating alert	RumiWatch,	Nose and leg: activity, intake, drinking, lameness rumination,	RF and USB, pressure, 3-axial accelerometer, thermistor,	http://www.rumiwatch.ch/index.html
	Celotor	Harness reader and tail inject	RF, SMS	http://www.celotor.com/celotor/partes-y-operacion
	Vel'Phone,	Vaginal temperature	Thermistor, SMS	http://www.medria.fr/en_GB/produits/vel-phone.html
Calving alert	iVET birth-monitoring	Vaginal temperature	Thermistor, SMS	http://www.birth-monitoring.com/home/birth-monitoring/
	Moocall	Tail ring	Accelerometer, SMS	http://www.moocall.com/
	eCow Devon	Rumen bolus: pH, temperature, drinking	RF, electrode, thermistor, pH,	http://www.ecow.co.uk/
Rumen function	San'Phone, Medria	Rumen bolus: temperature, drinking	Thermistor, SMS	http://www.medria.fr/en_GB/produits/san-phone.html
	Well Cow	Rumen bolus: pH, temperature	RF, electrode, Thermistor, pH	http://www.wellcow.co.uk/bolus/
	SmaXtec Sensor,	Rumen bolus: activity, temperature, drinking, oestrous	3-axial accelerometer, thermistor	http://www.smaxtec-animalcare.com/en/products-services/smaxtec-sensor/
Integrated functions	WildCell, Lotek	Neck	GPS, RF, temperature sensor, 2-axial accelerometer	http://www.lotek.com/wildcell.htm
Position location	CattleWatch	Neck	ear GPS, RF	http://www.cattle-watch.com/

[Source: (Caja *et al.* 2016)]

Table 2. Currently available non wearable sensing technologies for monitoring wellbeing of dairy animals

Objective	Manufacturer	Type & feature	Technology used	Reference link
Milk composition	AfiLab	In-line milk composition	Near-Infrared spectroscopy	http://www.afimilk.com/products/milking-parlor-automation/integrated-milking-point-analysiscontrol
Somatic cell Count (SCC)	OCC, DeLaval	Milk SCC by udder quarter	Analysis of cell ADN by UV fluorescence	http://www.delaval.com/en/-/Product-nformation1/Milking/Products/Stallwork/VMS-station/DeLaval-online-cell-counter-OCC/
Body condition scoring (BCS)	DeLaval BCS	Lower back image (loin, rump, hook, tailhead, fatness)	3D imaging	http://www.delaval.com/en/-/Product-Information1/Management/Systems/DeLavalbody-condition-scoring-BCS/
Metabolic biomarkers	Herd navigator	Biomarkers in milk	Fourier transform mid-IR	http://www.herdnavigator.com/pages/id1.html
Lameness	StepMetrix, BouMatic	Platform for gait consistency	Time and force sensor	http://www.boumastic.com/eu-en/products/view/stepmetrix
	Gaitwise, ILVO	Mat for gait consistency	Time and force sensor	http://www.dairycareaction.org/uploads/2/4/2/6/24266896/4.2_van_nuffel.pdf

[Source: (Caja *et al.* 2016)]

with an injectable transponder in the tail head which is read by the transceiver at mounting. Calving detection may be monitored by measuring tail movement patterns triggered by labour contractions, with devices attached to the tail head containing accelerometers (Moocall) or by the dramatic change of temperature of a vaginal device using thermistors when it is expelled during labour (Vel'Phone and iVET). Reticulo-rumen boluses (eCow, WellCow, smaXtec pH), assesses rumen function by specific sensors (e.g. temperature, pH, pressure) which might be related to rumen pH for SARA (subacute rumen acidosis) detection along with feeding and drinking behaviour.

Automated milking systems (AMS) for dairy cows are a good example of how non-wearable devices (Table 2) can be automated to help dairy husbandry staff by freeing-up time for tasks, which are simultaneously assisted by automatic and real-time data collection. Mastitis detection system has been developed such that a low cost screening by conductivity and behavioral analysis can be enhanced by automated somatic cell count (SCC) to validate diagnosis. Once the RFID has provided the identity, milk flow meters, milk conduct meters, infrared or laser assisted video cameras collect data that are then integrated in computers

by specific 'smart' software using complex algorithms previously validated with assumed standards, usually derived from observational data.

Wireless sensor network has number of advantages, a few are mentioned as below:

- Automatic recording and transmission of data without human intervention.
- Wireless technology reduces maintenance complexity and costs
- Suitable to monitor dangerous, hazardous, unwired or remote areas and locations
- Faster deployment and installation
- Flexible extension of the network
- Wireless sensors can be mounted on moving objects i.e. mobility of sensors

Despite great potential as recognized and supported by many enthusiastic industry alliances and users, adoption of such devices has not picked up. Main obstacles are as follows:

- Although manufacturers often claim to offer complete solution, no one system individually offers everything.
- Claims made for accuracy, precision, false positives and negatives in most cases have not been tested independently.

- Standardization is not yet completed.
- Security issues need to be resolved.
- Power supply is a concern for wireless systems.
- The reliability of wireless sensor system remains unproven.

SUMMARY

The use of IoT applications in agriculture has produced a number of advantages, including improved access to farm records, forecasting of plant diseases, improved crop protection, irrigation management, reduced resource waste, and the detection of patterns and trends, etc. Their overall objective is to assist good husbandry, not replace it, and the deliverable must be as simple as possible. Though IoTs are not devoid of disadvantages as of now, but advantages outnumber them. Besides IoTs coupled with AI technology have potential to give better return on investment for profitable farming. Use of sensors combined with communication technologies and AI for data handling are expected to produce rapid and dramatic changes in traditional agriculture and dairy farming systems.

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