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IT and IoT in Potato Cultivation

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Abstract

A series of challenges such as crop pests, diseases and climate change are being faced by potato growers. An innovative, market-ready smart farming solution can support efficient irrigation, pest management and fertilisation and can also provide inexpensive, valuable and timely advice to farmers.Adopting decision support system (DSS) in farming to prevent potato late blight disease has proven its utility. As a matter of fact, the DSS grants efficiency, and reduces production cost as well as the impact on the environment as it estimates the exact amount of fungicide that must be applied. Smart farming based on Internet of Things (IoT) technologies can enable potato or any other crop farmers to collect real-time data related to irrigation and plant protection processes, aiming to increase production volume, improve product quality and predict diseases, while optimizing resources and farming processes.The advanced HD cameras, better computing power and communication avenues offered by smartphones provide a promising platform for automated disease detection in crops, which can save time and help in the timely management of diseases, in cases of outbreaks.

Introduction to potato and smart farming

Potato (*Solanum tuberosum*) is the most important food crop of the world. In India potato is a temperate crop grown under subtropical conditions in India. The potato is a crop which has always been the ‘poor man’s friend’. It is being cultivated in the country for the last more than 300 years. For vegetable purposes it has become one of the most popular crops in this country. Potatoes are an economical food; they provide a source of low cost energy to the human diet. Potatoes are a rich source of starch, vitamins especially C and B1 and minerals. They contain 20.6 per cent carbohydrates, 2.1 per cent protein, 0.3 per cent fat, 1.1 per cent crude fibre and 0.9 per cent ash. They also contain a good amount of essential amino acids like leucine, tryptophane and isoleucine etc.

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Potato is grown in India under diverse agroclimatic conditions. The varieties should make the best use of the agroclimatic conditions and give high yield. Broadly the potato growing zones in India could be classified into the northern hills, the northern plains, the eastern hills, the plateau region and the southern hills. The growing season in the northern hills is the kharif season with long days. The crop experiences water stress during the emergence and initial growth phase while during the maximum bulking phase it is invariably exposed to late blight infection. Therefore varieties for this region requires resistance to late blight, should be able to withstand water stress, be able to yield well under long day conditions and the crop duration can be between 120 – 150 days. Presently KufriJyoti and KufriGiriraj are the main varieties for this region.

For vegetable purposes potato has become one of the most popular crops in India. It is an economical food and provides a source of low cost energy to the human diet. Potatoes are a rich source of starch, vitamins especially C and B1 and minerals. They also contain a good amount of essential amino acids like leucine, tryptophane and isoleucine etc. Potatoes are used for several industrial purposes also such as for the production of starch and alcohol. Potato starch (farina) is used in laundries and for sizing yarn in textile mills. Potatoes are also used for the production of dextrin and glucose. As a food product itself, potatoes are converted into dried products such as 'potato chips', 'sliced' or 'shredded potatoes'. Before processing or storing potatoes, it is important to know the eventual market and the specifications required of that market, which depends on a range of quality measures such as skin finish, dry matter, fry colour and sugar content. Crops should be assessed in relation to these parameters, both before and during processing and storage. The presence of rots and diseases or damage caused by bruising will have a significant effect on quality and the ability to meet customer specifications.

Smart farming based on Internet of Things (IoT) technologies can enable potato or any other crop farmers to collect real-time data related to irrigation and plant protection processes, aiming to increase production volume, improve product quality and predict diseases, while optimizing resources and farming processes.Potato Temperatures need to be monitored as it gives early warning of quality problems and the opportunity to take action before the situation gets worse. It also allows accurate and confident control and management of the stored crop. This temperature can be monitored in a wireless mode also using sensors.

Adopting decision support system (DSS) in farming to prevent potato late blight disease has proven its utility. As a matter of fact, the DSS grants efficiency, and reduces production cost as well as the impact on the environment as that it estimates the exact amount of fungicide that must be applied. This estimation uses environmental condition-based blight forecast model which, usually requires weather information collected from costly weather stations or precise historical data. However, climate data could be collected easily thanks to the evolution of the Internet of Things (IOT). In fact, this could be done by deploying a large number of low-cost, low-power sensor nodes inside farms.

Potato growers can plant and harvest potatoes more efficiently using expert advice. Machines equipped with sensors can be connected to the internet which provides farmers with various interesting perspectives, optimizes maintenance and functioning, and helps provide greater insight into agricultural processes. It can also read the sensors' parameters and measure crop yields. Farmers can also optimize the cultivation and fertilization of their land.

Marketing agricultural products is also very important part of the agriculture. Activities involved in it are planning production, growing and harvesting, grading, packing and packaging, transport, storage, agro- and food processing, provision of market information, distribution, advertising and sale. Internet and IoT can be used to plan digital marketing and hence make all these processes to work more efficiently.

Finally, mobile applications can be developed to help farmers in almost all the processes involved in agriculture right from seed production, planting, farm management, harvesting, packaging, advertising and selling and social media can be used to form farmers cooperatives wherein farmers can interact among themselves and share their problems related to farming. Experts would also be part of these social media groups.

Improving potato production efficiency

IoT is extensively being used in potato production in Poland, Ukraine and Cyprus – three countries with significant tradition in potato production – through NEUROPUBLIC's gaiasense smart farming system.

It forms the basis of an innovative market ready IoT solution which Nikolaos Kalatzis, the Use Case Coordinator, developed together with his team. In these regards, telemetric agro-environmental stations called Gaiatrons were installed in selected potato fields of these countries and smart farming services for the irrigation and crop protection of potato were developed and adjusted to the microclimatic and soil conditions of each area. The services aimed at reducing the costs of potato production per hectare of cultivation while improving its quality by using scientific models tailored to the specificities of the targeted areas, the different potato varieties and the unique requirements of the targeted markets. The models were fed with data from a network of GaiatronIoT stations collecting atmospheric (air temperature, relative moisture, wind direction and velocity, rain, leaf wetness) and soil measurements (temperature, moisture, salinity), satellite data (e.g. NDVI based on Sentinel 1 and 2), weather forecasts as well as individual data provided by the producers and agronomists involved, including information related to inputs and outputs. The use case innovation offered an inexpensive service with no technology related investment for end-users, making it accessible even to small farmers. Gaiatrons were specially designed to adopt to the operational requirements of the area they are installed in, ranging from a dense installation network under the canopy or large-scale deployment. The derived insights were leveraged by the agronomists and farming advisors consulting the involved farmers, who, in turn, fed the provided application with their own observations in order to produce the specialised advice on a case-by-case basis. This holistic approach relying on scientific knowledge alongside human experience was the main competitive advantage of the smart farming system. To give a better idea of the technological adaptability to the operational requirements, differences between the test farms needed to be studied. The Polish farm had a size of 97 ha and was divided in 3 parts each based on their identified soil and microclimatic differences. One IoT telemetric station was deployed in each part. In Ukraine, the total size of the test field was 119 ha, however due to the homogeneous conditions the researchers decided to deploy only one station there. To achieve an improved monitoring of the overall conditions, two additional stations were deployed in nearby fields. In Cyprus, three different fields utilised one station in each of them.

GAIA Cloud combined all the gathered information and converted it into actionable facts using advanced data analytic techniques. Moreover, the embedded decision support system (DSS) transformed these facts into an initial advice, which was accessible to farmers through the apps and certified agricultural advisor. The advisors reviewed and evaluated the given information for providing the final advice and support to the farmers, including fertilisation and irrigation recommendations alongside pest management warnings. Among the fundamental requirements of IoT technology services was to be able to operate with limited storage, computational and energy resources. In addition, in many cases the deployed smart farming innovation operated in highly demanding domains and in harsh conditions. Moreover, scarcity of resources combined with security and system administration related requirements forced engineers to apply custom,

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simple and practical solutions, tailored to the needs of each application domain, having as first priority the sound operation of the services.

Introducing data interoperability mechanisms to existing operational IoT environments is a challenging task with regards to the overall system performance. To this end, a set of design principles had been defined, aiming at the development of interoperability mechanisms able to be deployed on top of existing operational systems towards the realisation of a system-of-systems approach. The use case team thus focused on facilitating data sharing between gaiasense and other smart farming systems in a secure and efficient manner. Semantic and syntactic interoperability were realised through the use of standards such as NGSIv2 (APIs plus harmonised data models) as a universal mechanism for sharing context data of different nature. In addition, FIWARE Generic Enablers such as the Orion Context Broker were utilised for managing current context information. Having established the necessary interoperable data management mechanisms, advanced knowledge extraction and decision support is performed through data analytics algorithms. These process the data that was fed to the scientific models. Lastly, the end-user interaction with the underlying infrastructure was facilitated through a straightforward web-based application. For Nikos Kalatzis, IoT deployments need to rely on standards by their very initial design, making system interoperability an inherent feature in the future. However, a big part of the current IoT ecosystem is still far from such a realisation, which has motivated the researchers to lead the development of interoperability enables for their smart farming solution.

Smart farming for climate adaptation

Smart farming based on Internet of Things (IoT) technologies enables crop farmers to collect real-time data related to irrigation and plant protection processes, aiming to increase production volume, improve product quality and predict diseases, while optimizing resources and farming processes.

IoT devices collect vast amount of environmental, soil and crop performance data, thus building time series data that can be analysed to forecast and compute recommendations and deliver critical information to farmers in real time. In this sense, the added-value from the farmers' perspective is that such smart farming techniques have the potential to deliver a more sustainable agricultural production, based on a more precise and resource-efficient approach in the complex and versatile agricultural environment. The aim of this study is to investigate possible advantages of applying Smart Farming as a Service (SFaaS) paradigm, aiming to support small-scale farmers, by taking over the technological investment burden and offer next generation farming advice through the combined utilization of heterogeneous information sources. The overall results of the pilot application in Cyprus demonstrate a potential reduction of up to 22% on total irrigation needs and important optimization opportunities on pesticides use efficiency. The current work offers opportunities for innovation targeting and climate change adaptation options (new agricultural technologies), and could help farmers to reduce their ecological footprint. To achieve this goal, the researchersteam engaged with the ecosystem of local stakeholders in each country to co-design and test the solution, following the lean start-up methodology. Doing this at an early development stage helps the iterative development process, which is based on the definition of requirements, forming the design guidelines of the solution. To this end, the local partners actively collaborated with a wide network of farmers and agronomists in their respective areas. Smart farming techniques can only unleash their full potential in terms of mitigating climate change if all stakeholders are taken into consideration.

Before processing or storing potatoes, it is important to know the eventual market and the specifications of that market required. Specifications will depend on a range of quality measures such as skin finish, dry matter, fry colour and sugar content. Crops should be assessed in relation to these parameters, both before and during processing and storage. The presence of rots and diseases or damage caused by bruising will have a significant effect on quality and the ability to meet customer specifications.

Quality Control is an investment. Initial inspection of loads to check for bruising damage and the presence of rots will determine if the loads can be safely taken into storage or need to be processed immediately. Once in the store, monthly monitoring of factors that are likely to change, such as sprouting, rots, fry colour and certain blemish diseases should be carried out.

Three reasons to measure Potato Temperatures

- Temperature monitoring gives early warning of quality problems and the opportunity to take action before the situation gets worse

- Monitoring shows whether temperature targets have been reached – which can save energy by avoiding unnecessary ventilation use

- Monitoring allows accurate and confident control and management of the stored crop

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Barn Owl Wireless is a modular multi-sensor monitoring and automatic ventilation control system. The flexibility of the system makes it ideally suited to potato store monitoring in all sizes and types of store.

How Barn Owl Wireless works

Wireless radio transmitters are attached to flexible crop sensors in boxed or bulk stored potatoes. Temperature data is transmitted by SIM card to the internet and can be accessed from any location. Automatic fan controllers give independent control of each ventilating fan using a range of programmes, providing significant energy cost savings.

Steps of the Barn Owl Wireless working

1. Temperature data in the potato store is sent to the gateway

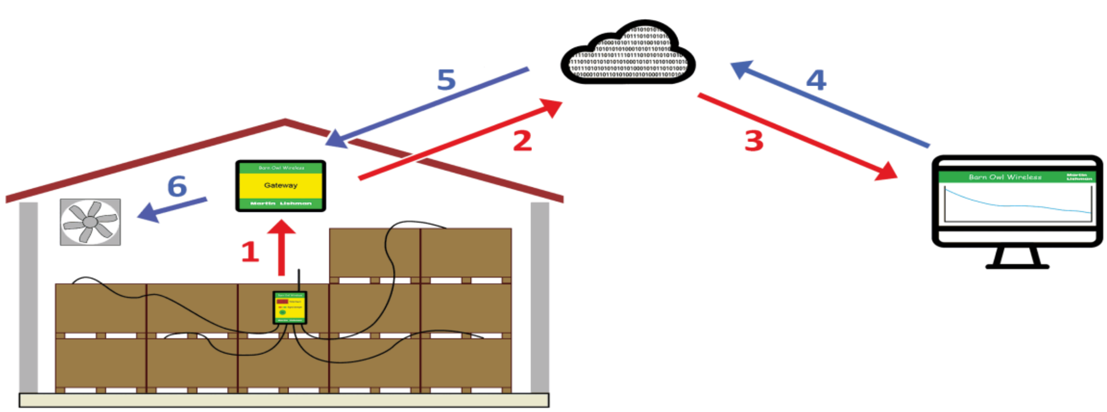
2. Data is sent to the cloud via the GSM network

3. Data on the webpage is accessed via the Internet

4. Fan controls are selected on the webpage

5. Fan controls are sent to the gateway

6. Fan controls are sent to fan controllers to turn on/off extraction fans



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IIT Mandi Example

Researchers at the Indian Institute of Technology (IIT) Mandi, have developed a computational model based on Artificial Intelligence (AI) for automated disease detection in potato crops using photographs of its leaves.

The research in collaboration with the Central Potato Research Institute, Shimla, used AI techniques to highlight the diseased portions of the leaf. The computational tool developed by IIT Mandi scientists can detect blight in potato leaf images. The model is built using an AI tool called mask region-based convolutional neural network architecture and can accurately highlight the diseased portions of the leaf amid a complex background of plant and soil matter.
The researchers are further working on converting the developed tool to a smartphone application for a more practical usage.

According to the team, potatoes, in the history of the world, have been the cause of the great famine of the mid-nineteenth century that killed over a million people in Ireland and rang the death knell for the Irish language. The reason was Potato Blight.

In India, as with most developing countries, the detection and identification of blight are performed manually by trained personnel who scout the field and visually inspect potato foliage.This process, as expected, is tedious and often impractical, especially for remote areas, because it requires the expertise of a horticultural specialist who may not be physically accessible.

Joe Johnson, research scholar at IIT Mandi explained that the automated disease detection can help in this regard and given the extensive proliferation of the mobile phones across the country, the smartphone could be a useful tool in this regard.The advanced HD cameras, better computing power and communication avenues offered by smartphones have been quite helpful in designing the tool. For the research, in order to develop a robust model, healthy and diseased leaf data were collected from fields across Punjab, Uttar Pradesh and Himachal Pradesh.

The seven-member team claimed even though potato is not a staple food in most regions of the world, it is a cash crop, and failure in it can have disastrous consequences, particularly to farmers with marginal landholding.Thus, early detection of blight is important to prevent financial catastrophe to the farmer and the country’s economy.

With this timely knowledge, the farmer would know exactly when to spray the field, saving his produce and minimising costs associated with unnecessary use of fungicides.

IT and IoT initiatives at ICAR-CPRI

There have been many initiatives at ICAR-CPRI concerned with applying the IT and IoT for potato cultivation and disseminating important cultivation related information to the potato farmers. The technologies which have been developed and are available on the CPRI Web server. Some of these are :

1. ICAR-CPRI Website
2. Potato Master mobile app
3. E-books on potato, potato storage systems in India, potato processing scenario in India and Agro-techniques for Production of Quality Potato seed
4. CPRI Web and application server on which various tools/DSS/ebooks have been hosted
5. Potato SSR Database

In addition to these technologies, an extensive use of social media is on the way wherein farmers would be given advice regarding cultivation through WhatsApp groups and videos would be launched on Youtube channels for their knowledge.

Conclusion

There is no doubt that IT and IoT technologies can play a very important part in making the potato farmers aware about the automated disease detection which can helpthem and given the extensive proliferation of the mobile phones across the country, the smartphone could be a useful tool in this regard. Its potential, till date, has not been fully harnessed. The smart technologies can be harnessed to disseminate latest cultivation technologies to the farmers as well as in marketing of the product. Hence IT and IoT technologies, if harnessed efficiently, can play a very important role in decreasing the input costs and increasing the productivity and quality of potato as well as its post harvest technologies.