Potato J (2015) 42 (1): 44-49

VALIDATION OF JHULSACAST MODEL USING HUMAN PARTICIPATORY SENSING AND WIRELESS SENSOR NETWORKS

Bhushan Jagyasi[1], Vikrant Kumar[1], Arun Pande[1], BP Singh[2], Mehi Lal[2], Islam Ahmad[2] and Prakash Lohia[3]

ABSTRACT: A wireless sensor network was deployed using four sensor nodes to collect temperature and humidity data from the farm in a region of interest. This study demonstrated implementation of the Central Potato Research Institute's Jhulsacast model for forecasting of potato late blight disease using these sensor observations. A novel human participatory sensing mobile phone application was developed for diagnosis of the disease at the farm level. The validation of the Jhulsacast model, and its comparison with other models was done using the human participatory sensing approach. The study indicated that unlike the existing methods which rely on disease forecasting to control the plant diseases, the decisions on pesticide application can be made by jointly considering diagnosis and forecasting information. Experimental results depicted that the Jhulsacast Model has been found to be significantly accurate than the Ullrich, Fry, Winsteland Wallin models for the Hapur region of Uttar Pradesh, India.

KEYWORDS: Human Participatory Sensing Jhulsacast, Wireless Sensor Network.

INTRODUCTION

Late blight disease, caused by *Phytophthora infestans*, is a very serious disease of potato. It can destroy the entire crop in less than two weeks time. Worldwide losses due to late blight could be up to USD 12 Billion per year (Haldar *et al*., 2006; Judelson *et al.,* 2005, Arora et al. 2014). Several late blight disease forecasting models have been developed throughout the world (Ullrich, 1966; Fry, 1983; Winstel, 1993; Wallin, 1962, 1951; Arora *et al*., 2014). In India, Jhulsacast model (Singh *et al*., 2000) has been developed by Central Potato Research Institute for western Uttar Pradesh region. Most of these models have been developed considering data obtained for a particular region and these models as such were found to be more accurate only for some selected regions. A novel framework in which farmers can submit, using a mobile phone application, the information on the symptoms along with cumulative composite disease risk can lead to more accurate advice for the farmers (Pande *et al*., 2009).

Wireless sensor networks (WSNs) are useful for a wide range of applications in domains such as automation, agriculture, transport, military, oil ore extraction, water, pharmaceutical, health, disaster detection and surveillance (Akyildiz *et al*., 2002). With the increasing convenience in deployment, portability and affordability of wireless sensor nodes, recently WSN's have been found to be useful for the deployment in farms for several agriculture applications such as control of pest attacks, yield optimization, and automation and optimization of irrigation, leading to a precision farming scenario (Neelamegam *et al.,* 2007; Wark *et al.,* 2007). In this study, deployment of a Wireless Sensor Network

[1]TCS Innovation Labs, Tata Consultancy Services, Thane (W)-400 601, Maharashtra, India.
Email: bhushan.jagyasi@tcs.com
[2]ICAR-Central Potato Research Institute, Simla-171 001, Himachal Pradesh, India.
[3]Merino Industries, Hapur-245 101, Uttar Pradesh, India.

(WSN) formed by four sensor nodes was carried out at a potato farms in Hapur, for obtaining hourly temperature and hourly humidity observations. The aggregated sensor readings were used to compute the disease risk from various late blight disease forecasting models.

In recent literature (Bulusu *et al. 2008*; Dua *et al.,* 2009; Reddy *et al.,* 2009; Rekimoto, 2009) there has been a strong focus towards Urban Sensing, in which human participatory sensing is done for several urban applications like, smart cities, pollution detection and traffic management. A Rural Participatory Sensing (RuPS) mobile application has been proposed in this paper which undertakes the participatory sensing in a rural setup for the detection of plant diseases. The RuPS mobile phone application was developed and made available to the farm supervisors at Hapur to report the symptoms observed along with images of the infected plants. This information was used for the diagnosis of the disease and to validate the Jhulsacast model for the Hapur region. The results obtained by Jhulsacast model were compared with other late blight forecasting models developed elsewhere.

MATERIALS AND METHODS

Wireless sensor networks

A wireless sensor network was deployed in a selected farm at Hapur using four sensor nodes. Each sensor node possessed a transceiver to facilitate communication with neighboring nodes, micro controller for processing data and executing algorithms, batteries with integrated solar charging unit, and ports to integrate the required sensors. Temperature and humidity sensors were connected on the ports of the sensor nodes through a long cable which helped in placing the sensors in the plant canopy, while the communicating part of the node got mounted high up on the pole to facilitate a long range communication to the other sensor nodes. The data sensed from sensor nodes was communicated to the sink node which was connected to the Gateway node. The Gateway running on a Linux operating system had access to the internet, through which the observed sensor data got periodically uploaded in the sensor database. The temperature and humidity observations were made from 24 November 2011 to 8 February 2012, which is the potato season at Hapur, Uttar Pradesh.

Temperature and humidity values, obtained from the weather station were used, for computing disease risk using late blight disease forecasting models like Ullrich (Ullrich, 1966), Fry (Fry, 1983), Winstel (Winstel,1993), Wallin (Wallin, 1962, 1951) and Jhulsacast (Singh *et al*., 2000) and results were compared.

Rural Participatory Sensing

A Rural Participatory Sensing (RuPS) mobile phone application was used to collect the symptoms of the late blight disease as shown in **Fig. 1** by asking six questions on different symptoms of the disease. For each of the question, farmer could provide a binary response indicating a positive or negative observation on those symptoms by pressing either ‘Yes’ or ‘No’, respectively. For the convenience of the farmer and to make the questions accurately understood, there was an option to select the local language for the text to appear in the local script on the phone screen. Finally, to make this application useful even for the farmers who cannot read, sample photographs of the disease infected leaf, stem and tuber, were provided which were aligned to the question asked.

The mobile application is indeed a human participatory sensing approach, wherein the farmer uses his/her senses to observe the symptoms of the disease and hence participate

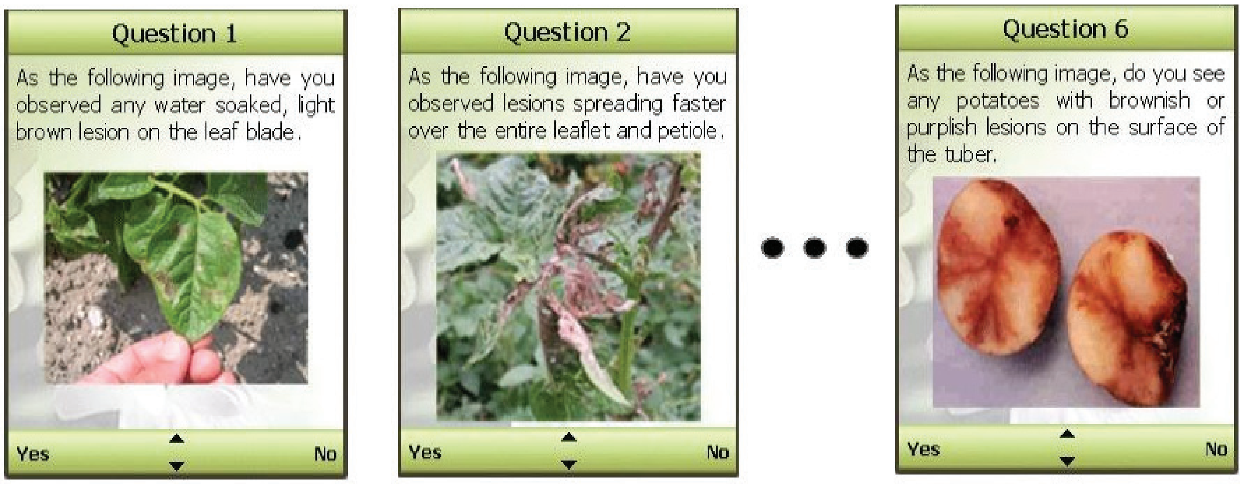

Fig. 1 Rural Participatory Sensing (RuPS) mobile phone application for disease diagnosis

in the sensing phenomenon. Through this RuPS application, we propose a paradigm shift in plant disease management in which the human being participates in the detection process, thereby contributing towards quick availability of the data for the remote detection of the disease. Appropriate training can be provided to the farmers for identifying the correct symptoms in order to improve the accuracy of the detection. The information on symptoms submitted by the farmers in the form of 'Yes' and 'No' is used to compute the 'disease severity'. After responding to the six questions, the user is also facilitated to capture a few photographs of the infected areas of the plant and record a voice clip to support their observation of symptoms.

We hence strongly believe that the combined consideration of forecasting (disease risk) and diagnosis (disease severity) can improve the confidence in the recommendations made regarding the dosage of pesticides. The information of disease risk and disease severity is provided on the map interface, which can be accessed from the internet. This disease console is a powerful analysis tool for the plant disease epidemiology. This novel mobile phone based disease diagnosis approach, facilitates the usage of information obtained from the neighboring farms and neighboring villages along with the wind direction to more accurately forecast the disease risk and to provide farm-specific personalized advises to farmers. The feedback from farmers on the disease severity also helps to tune the model for a specific region or even for a specific farm.

Dissemination of Alerts

A web based disease analysis console was developed through which the expert could visualize the disease risk and the farm level disease diagnosis results that includes symptoms and photographs of infected plants. The expert was facilitated to send the alerts quickly and simultaneously to a large number of farmers in a selected region in order to provide timely information about the disease risk.

RESULTS AND DISCUSSION

The four sensor nodes were deployed in a farm of thirty three acre (approximately 13.5 hectare) area at Hapur, Uttar Pradesh. Each sensor node was programed to sample temperature and humidity at 15 minutes sampling interval. Sixteen observations per hour made by the WSN formed by these four sensor were averaged for obtaining more accurate temperature and humidity readings. These aggregated hourly observations of ambient humidity and temperature were used for computing disease risk using different disease forecasting models. The photographs of the disease infected leaves collected through the Rural Participatory Sensing (RuPS) mobile phone application assisted in the accurate diagnosis of the disease.

Fig. 2 presents the disease risk computed by CPRI's Jhulsacast model in comparison with the days on which the actual disease attack was observed using RuPS application. Similarly, **Fig. 3** and **Fig. 4** present the disease risk obtained from Winstel and Wallin; and Ulrich and Fry models, respectively, in comparison with the actual disease attack. The Jhulsacast model was able to indicate the high disease risk, at least three days in advance. Further, because of binary values of disease risk provided by the Jhulsacast model, there was no ambiguity about the occurrence of the disease. However, in other models, there is some work required related to the selection of threshold. For instance, from **Fig. 3**, if a threshold of 20 is selected then Winstel model is able to forecast the inoculum up to 5 days in advance. However, Ulrich, Fry and Wallin models lead to many false alarms. These results hence clearly indicate that among the various models that were implemented, the Jhulsacast model of CPRI was found to be most reliable for the forecast of the first inoculum in the Hapur region.

CONCLUSIONS

The existing approaches for the control of potato late blight disease are based on modeling the sustained conducive environment in order to forecast the occurrence of the disease. This paper demonstrated deployment of wireless sensor network to collect spatially and temporally high resolution sensors data for more accurate forecasting of disease using CPRI's Jhulsacast model. The comparison of the performance of Jhulsacast model with other available late blight forecasting models was also presented. Further, a rural participatory sensing mobile phone application was shown to facilitate remote diagnosis of late blight disease. The participatory sensing approach provides two fold advantage, that is, in validation of disease forecasting models

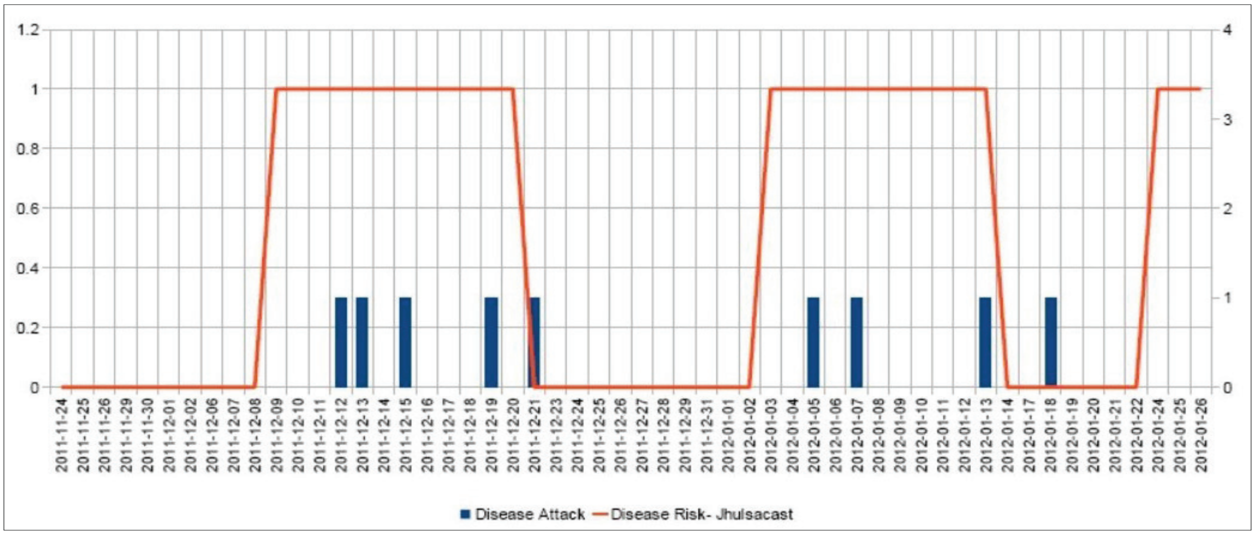

Fig. 2. Late Blight Disease Risk computed from CPRI's Jhulsacast Model

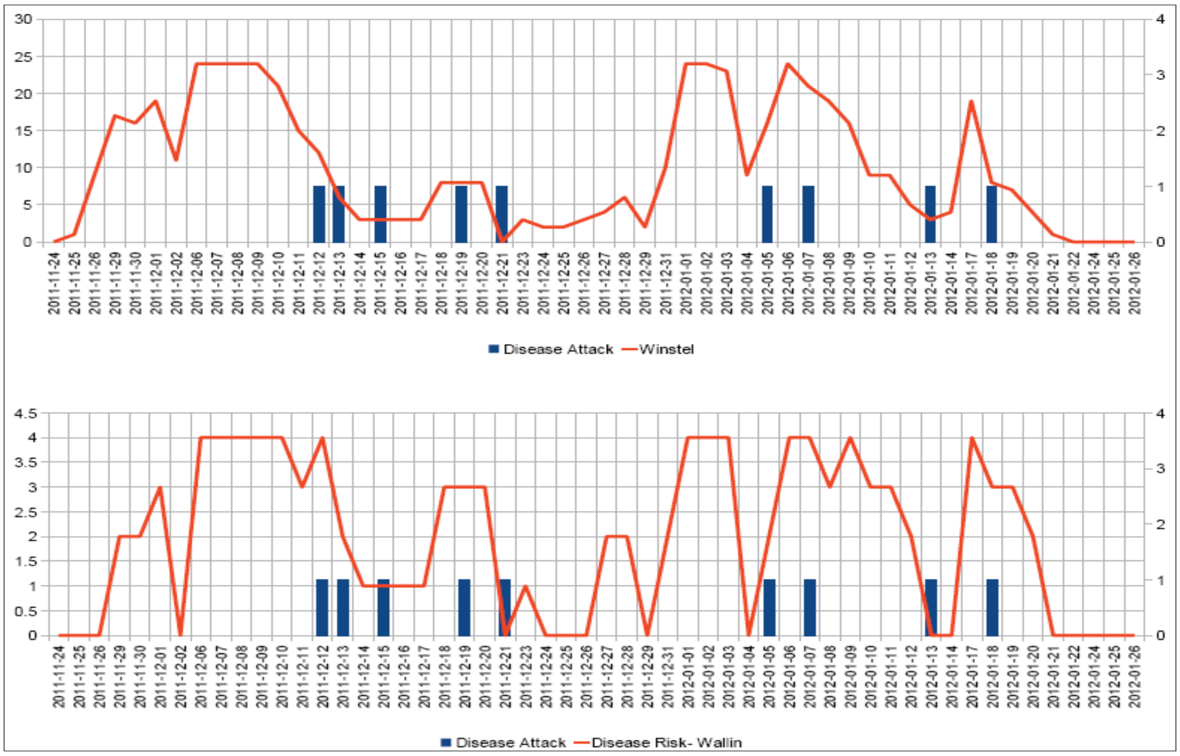

Fig. 3. Late Blight Disease Risk computed from Winstel and Wallin Models

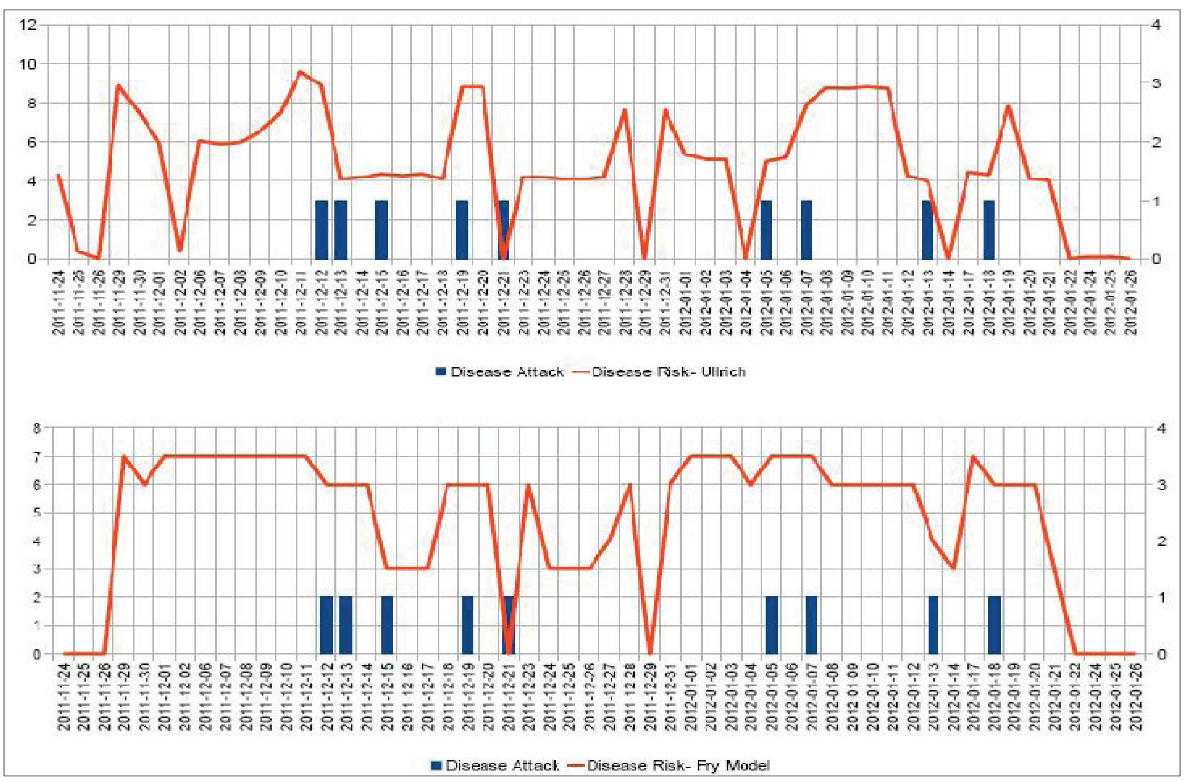

Fig. 4. Late Blight Disease Risk computed from Ullrich and Fry Model

and in making the farm level personalized decisions on pesticide spraying.

ACKNOWLEDGEMENTS

We acknowledge other team members of Merino Industries at Hapur and Central Potato Research Institute at Shimla and Modipuram for their support and advice during the implementation of this project.

LIERATURE CITED

Akyildiz LF Su W, Sankarasubramaniam Y and Cayirci E (2002) A survey on sensor networks.

IEEE Commun Magazine **40** (8): 102-114

Arora RK, Sharma Sanjeev, Singh BP (2014) Late blight disease of Potato and its management. *Potato J. (2014)* **41**(1): 16-40

Bisht GS, Harish S and Singh H (1997) Fungal diseases of useful plants in the Garhwal himalaya and their managment. S C Sati, J Saxena, and R. C. Dubey (eds.). Himalayan Microbial Diversity. Today and Tomorrow's Printers and Publishers, New Delhi, India. 255-71p

Bulusu N, Chou CT, Kanhere S, Dong Y, Sehgal S, Sullivan D and Blazeski L (2008) Participatory sensing in commerce: Using mobile camera phones to track market price dispersion. In, Proceedings of the UrbanSense, Raleigh, NC, USA, 4 November 2008

Dua A, Bulusu N, Feng WC and Hu W (2009) Towards trustworthy participatory sensing. In, Proceedings of the 4th USENIX conference on Hot Topics in Security, Montreal, Canada, 11 August 2009

Fry WE., Apple AE and Bruhn JA (1983) Evaluation of potato late blight forecasts modified to incorporate host resistance and fugicide weathering. *Phytopatholo* **73**: 1054-59

Haldar K, Kamoun S, Hiller NL, Bhattacharje S and van Ooij C (2006) Common infection strategies of pathogenic eukaryotes. *Nat Rev Microbiol* **4:** 922-931, DOI 10.1038/nrmicro1549

Judelson HS and Blanco FA (2005) The spores of phytophthora: weapons of the plant destroyer. *Nat Rev Microbiol* **3**: 47-58. DOI 10.1038/nrmicro1064

Neelamegam S, Naveen CPRG, Padmawa M, Desai UB, Merchant SN and Kulkarni V (2007) Agrisens: Wireless sensor network for agriculture - a Sula vineyard case study. In, Proceedings The International Workshop on Wireless Sensor Network Deployments, Santa Fe, USA, 18-20 June 2007

Pande A, Jagyasi BG and Choudhuri R (2009) Late blight forecast using mobile phone based agro advisory system. In, Proceedings of the Third International Conference on Pattern Recognition and Machine Intelligence, New Delhi, India, 16-20 Dec 2009

Rao ANS and Veeresh GK (1989) Estimation of yield loss due to late blight in rainfed potato. *Current Research- University of Agriculture Sciences Bangalore* **18**(11): 157-158

Reddy S, Samanta V, Burke J, Estrin D, Hansen M and Srivastava M (2009) Mobisense mobile network services for coordinated participatory sensing. In, Proceedings of the International Sym- posium on Autonomous Decentralized Systems, 2009. ISADS '09: 1-6. DOI 10.1109/ISADS.2009.5207328

Rekimoto J and Sensonomy (2009) Intelligence penetrating into the real space. In, Proceedings of the 14th International Conference on Intelligent User Interfaces, IUI '09, pp. 3-4. ACM, New York, USA. DOI http://doi.acm.org/10.1145/1502650.1502653

Singh BP, Ahmad I, Sharma VC, Shekhawat GS (2012) Jhulsacast: a computerized forecast of potato late blight in western Uttar Pradesh. *J Indian Potato Asso* **27** (1/2): 25-34 (2000)

Ullrich J, Schrodter H (1966) Das problem der vorhersage des aufretens der kartoelkraut- faule (phytopphthorainfestans) und die moglichkeit seinor losung durch eine negativprognose. *Nachrichtenblatt Dt. Panzenschutzdienst (Braunschweig)* **18**: 33-40

Wallin JR (1951) Forecasting tomato and potato late blight in the northcentral region. *Phytopatholo.* **41**: 37

Wallin JR (1962) Summary of recent progress in predicting the late blight epidemics in United States and Canada. *Am Potato J* **39**:386-12

Wark T, Corke P, Sikka P, Klingbeil L, Guo Y, Crossman C, Valencia P, Swain D and Bishop Hurley G (2007) Transforming agriculture through pervasive wireless sensor networks. *IEEE Pervasive Computing* **6** (2): 50-57. DOI http://dx.doi.org/10.1109/MPRV.2007.47

Winstel K (1993) Krautund knollenfaule der kartoel eine eeue prognosemoglichkeit-sowie bekampfungsstrategein. Med. Fac. Landbouww. Univ Gent. **58**/32b

MS received: 18 November 2014; Accepted: 19 June 2015