Research Article

A Kalman Filter Uses in Mexican Agriculture

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Abstract

Currently, any country on the planet has problems feeding its population, which is getting bigger every day. Due to this situation, researchers dedicated to food production are increasingly pressured to increase their production, for this they make use of any technique that can help them; new technologies seem to be the only viable alternative. From the reviews carried out in articles from other countries, the use of this method in navigation systems is notoriously important. In Mexico, as this field is incipient, the application of the Kalman filter is also used for other types of research such as irrigation, agricultural economics agrometereology and models of crop growth as researchers focus on more current topics such as aerial and land unmanned agricultural vehicles the use of this important tool will also be greatly increased due to its benefits and applications in navigation.

Introduction

Currently, any country on the planet has problems feeding its population, which is getting bigger every day. Due to this situation, researchers dedicated to food production are increasingly pressured to increase their production, for this they make use of any technique that can help them; new technologies seem to be the only viable alternative. Mexico does not escape the aforementioned, therefore the automation of agriculture, livestock and other production biosystems such as greenhouses [1] seems to be an option currently, through the Internet of Things[2] mechatronics [3], machine vision [4,5]. The use of drones and other autonomous vehicles [6], within the latter, autonomous navigation is important and within this, the use of the kalman filter is of great importance, which is why this bibliographic research work was carried out.

Materials and Methods

Was made use of a review of academic articles, textbooks, internets materials, news articles and publicly available materials on housing problems. A systematic and thorough search was conducted for data collection in printed databases, Internet, magazines scientific, graduate and postgraduate university thesis, newspaper articles, etc. The method used is a review of academic articles, textbooks, internet materials, news articles and publicly available materials.

Literature Review

The Kalman filter is an efficient, recursive, mathematical algorithm that processes, at each step, inaccurate observation input data and generates a statistically optimal estimate of the subjacent real system state, by employing a prediction model and an observation model. Rudolf E. Kalman in 1960 developed it and it is an algorithm that serves to identify the hidden state (not measurable) of a linear dynamic system, when the system is subjected to additive white noise, it is a recursive algorithm, it can run in real time using only current input calculations, the previously deduced state and its suncertainty matrix, and does not demand any other additional information, it has numerous applications in technology [7]. A common application is the guidance, navigation and control of vehicles, mainly spaceships. Furthermore, it is widely used in fields such as signal processing and econometrics (Table 1).

Kalman Filter in Mexican Agriculture

In our country, the kalman filter has been used recurrently in agricultural research, in different fields from irrigation, economics, plant growth models, to autonomous navigation in agricultural vehicles; Ruiz[8] developed the NICOLET model to predict biomass production and nitrate content of lettuce production, and used the kalman filter is a suitable method to provide the required automatic adaptation to time-varying phenomena in complex crop models.Sanchez [9] presents a methodology based on space-time geostatistics for the optimal design of automated monitoring networks, using as optimization criteria to reduce the variance of the error in the estimation of groundwater levels in certain space-time positions given a frequency fixed monitoring; Using the Kalman filter, the variance of the error in the estimation was calculated based on the position of the monitoring sites, without the need to know the data measured in the field. Begovich [10] implemented and evaluated in real time an optimal LQG controller, to regulate; In the face of variations in the flow entering, the canal, the levels upstream of the gates in a four-channel irrigation channel prototype, using an upstream control, also made use of the Kalman filter. Loría[11] estimated the dynamic relationship between the unemployment rate and the Mexican product, with annual data (1970-2004). I use three time series structural models with the Kalman filter. Serrano [12] implemented the Kalman filter to estimate the states and outputs of the dynamic growth model of lettuce *(Lactuca Sativa)* NICOLET B3 from real measurements with simulated random disturbances that allowed validating the model.Ruiz [13]applied an Optimal Linear Gaussian regulator in the downstream control of a two-section laboratory channel.Ortiz [14] presents robust simultaneous mapping and mapping applied to trajectory planning, in other words, a technique for the problem of autonomous navigation of nonlinear systems. It is proposed to modify the Extended Kalman Filter using the first-order sliding mode theory that has the characteristic of being robust to bounded disturbances and uncertainties in mathematical models. INECC [15] Present the Economic Modeling of the Agriculture, Forestry and Other Land Uses sector (AFOLU) for estimating greenhouse gas emissions and short-lived climate compounds. The simulations were built using an algorithm that combines the Metropolis-Hastings algorithm and the Kalman filter.Perez [16]Present out a work designed for the use of the Discrete Kalman Filter algorithm that helps alert or knowledge of possible hydro meteorological phenomena for the central basins of the state of Veracruz.Gutierrez [17] presented the results obtained by implementing an extended Kalman filter to estimate the orientation states of a quadcopter. These states are assumed to be measured through an accelerometer and a gyroscope, both measurements presenting channel noise. First, the model used for the flight simulation is shown, which is non-linear, so to use the Kalman Filter algorithm it is necessary to linearize and discretize

Table 1: Kalman Filter in World Agriculture.

Author	Description	Year
Ming Li	Mentions that this computational method is necessary to improve usage of the integration of gps with Inertial Navigation System (INS)in the autonomous guidance system of agricultural vehicles	2009
Yuliang Zhang	Describes a numerical robust and computational efficient square-root central difference Kalman filter (SRCDKF) and put it into the application of state estimation of Inertial Navigation System (INS)/GPS integrated navigation for wheeled agricultural robot to overcome the flaws exist in EKF (Extended Kalman Filter).	2008
Freitas	Addresses the refactoring of an agricultural vehicle localization system and its deployment and field-testing in apple orchards. It employs an Extended Kalman Filter to integrate the information from the sensors, with the pose being predicted via encoder odometry and updated via point and line features detections	2012
Laia	Use of unscented Kalman filter with neural networks in a dual estimation filtering: a filter for state estimation and a filter for weight estimation with the objective of obtaining better quality in the signal / noise relation of Agricultural soil tomographic projections	2008
D. Wu	Presents an adaptive steering controller using a Kalman estimator for wheel-type agricultural tractorsfor achieving accurate and prompt steering control with noisy steering command signals and drifting valve characteristics on an automated agricultural tractor with an electrohydraulic steering system.	2001
Oksanen	Improved tractor positioning with a cheap GPS-receiver by using inertial navigation and odometry. Kalman filtering is used for sensor fusion	2005
Southall	Prents a work concerned with a machine vision system for an autonomous vehicle designed to treathorticultural crops. The vehicle navigates by following rows of crop (individual cauliflower plants) that are planted in a reasonably regular array typical of commercial practice. We adopt an extended Kalman filter approach where the observation model consists of a grid, which is matched to the crop-planting pattern in the perspective view through the vehicle camera.	2002
Anadranistakisa	Developed a correction method for the provision of accurate near-surface temperature and humidity forecasts, based on the combination of a Kalman theory filtering technique and an empirical method with exponential smoothing.	2004
CHEN	Introduceda PyWOFOST model based on Ensemble Kalman Filter(EnKF) to assimilate LAI into crop model.Meteorological data,agro-meteorological data and MODIS LAI data were used to test the applicability of PyWOFOST model in simulating maize yield in Northeast China.	2012
Xiaoyun	Studies the application of Kalman filter in agricultural economic forecasting. At first it introduces the multivariate Bayesian dynamic linear model with the Kalman filter, then gives some knowledge about subjective intervention.	1996
J. Koo	Development The DSSAT-CENTURY model and the ensemble Kalman filtering method to estimatesoil carbon,crop biomass,and a model parameter amd specifies the raye of soil organic matterdecomposition	2007
Jawoo Koo,	Used The DSSAT-CENTURY model and the Ensemble Kalman Filtering (EnKF) method to test if this approach can reduce the soil carbon measurement error. A base case simulation study was setup with maize farming system in Ghana for 50 years.	2003
Fang-ming Zhang,	Developed A real-time positioning system, which consists of a NIR camera, a turning angle sensor, and two encoders, forfield vehicle applications. A position-attitude (PA) model was designed and extended Kalman filter was used to integrate the signals from these sensors to output accurate position estimation.	2006
De Wit	Used an Ensemble Kalman filter (EnKF) to assimilate coarse resolution satellite microwave sensor derived soil moisture estimates (SWI) for correcting errors in the water balance of the world food studies (WOFOST) crop model. Crop model simulations with the EnKF for winter wheat and grain maize were carried out for Spain, France, Italy and Germany for the period 1992–2000.	2007
Libby	Presents a perception-based GPS free approach for localizing a mobile robot in an orchard environment. An extended Kalman filter (EKF) algorithm is presented that uses a wheel odometry prediction step and laser rangefinder update steps	2011
Park	Develop The aerial application using an unmanned agricultural helicopter has been already utilized in Japan and Korea. an affordable attitude measurement system using a conventional Kalman filter algorithm that would be applied in an affordable agricultural unmanned control system.	2011
Hongyuan	Estimating regional winter wheat yield by assimilation of time series of HJ-1 CCD Normalized Difference Vegetation Index(NDVI) into WorldFood Studies(WOFOST)–ACRM model with Ensemble Kalman Filter	2013
Hague	Examines ground based (as opposed to satellite based) sensing methods for vehicle position fixing. Sensors are considered in various categories, motion measurement (odometry, inertial), artificial landmarks (laser positioning, millimetre wave radar), and local feature detection (sonar, machine vision). The most common technique, the Kalman filter, is outlined and practical points are discussed.	2000
Luan	Applied classic Kalman filter to estimate the greenhouse states and lter out the noises, where some or all measurements are lost in a random fash-ion.	2011
Duggal	Described a framework, which performs plantation monitoring, and yield estimation using the supervised learning approach, while autonomously navigating through an inter-row path of the plantation. The proposed navigation framework assists the quadcopter. The proposed framework utilizes fusion of data from IMU and visual SLAM with extended Kalman filter (EKF) to address the limitations of systems using only GPS or IMU	2016
Mourik	Explored model based filtering. The focus was on estimating the average climate inside a greenhouse compartment. Starting point was employing an extended Kalman filter (EKF), combined with a greenhouse climate differential equation model.	2019

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Zhang	Describes a numerical robust and computational efficient square-root central difference Kalman filter (SRCDKF) and put it into the application of state estimation of Inertial Navigation System (INS)/GPS integrated navigation for wheeled agricultural robot to overcome the flaws exist in EKF (Extended Kalman Filter).	2008
Penizzotto,	proposes a fusion of states obtained from two sensors, odometer and GPS, each one working with its respective sampling time, which may or may not coincide with the sampling time of the controller system. An Extended Kalman structure, based on the kinematic model of the uni-cycle type robot, is used to filter and prepare the signals before being merged.	2008
Sorensen	Modeled the continuous time dynamics of (log□) commodity prices as a sum of a deterministic seasonal component, a non□stationary state□variable, and a stationary state□variable. Futures prices are established by standard noarbitrage arguments and the Kalman filter methodology is used to estimate the model parameters for corn futures, soybean futures, and wheat futures based on weekly data from the Chicago Board of Trade for the period 1972–1997.	2002
Hansen	Describes the use of derivative free filters for mobile robot localization and navigation in an orchard. The localization algorithm fuses odometry and gyro measurements with line features representing the surrounding fruit trees of the orchard	2011
Bolten	Attempt to correct for the errors by designing and applying an Ensemble Kalman filter (EnKF) data assimilation system to integrate surface soil moisture retrievals from the NASA Advanced Microwave Scanning Radiometer (AMSR-E) into the USDA modified Palmer soil moisture model	2010
Zhang	Adopted An electric bicycle as experimental platform and system performance with two positioning methods of automatic navigation respectively and was analyzed, the one was GPS positioning method and the other was the method based on a fusion of two data source(RTD DGPS and digital compass)by Kalman filter.	2009
Ying	Studied a new navigation method to improve the position accuracy. The compensate model is built to compensate for the libration caused by the antenna. A Kalman filter is developed, and a VRS-based receiver is used as the low accuracy GPS. The Kalman filter is applied to the data collected from the low accuracy GPS, compass and speed sensor.	2009
Huanyu	Built A platform up to collect the pressure data near the nozzle.The instantaneous flow data was calculated based on the relationship between pressure and flow by using Kalman filtering algorithm.	2014
Dorvigny	Present a navigation solution based on the Kalman Extended Filter. The inertial sensor measurements of the Low cost with GPS measurements to estimate the estimation of the position and speed of an autonomous vehicle	2018
Marchant	Establish the accuracy of an autonomous vehicle working in a field of transplanted cauliflowers. The main sensing systems, odometry and image analysis, are briefly described as is the control system which is based on a fusion of the two data sources using a Kalman filter.	1997
Gomez	Study to reduce the quantization errors of some low-cost GPS receivers by using a Kalman filter. Kinematic tractor model equations were employed to particularize the filter, which was tuned by applying Monte Carlo techniques to eighteen straight trajectories, to select the covariance matrices that produced the lowest Root Mean Square Error in these trajectories.	2013
Hamouda	Introduced Smart heterogeneous precision agriculture (SHPA) using a wireless sensor network for limited energy sensor nodes, deployed in an agricultural farm which is divided into a number of heterogeneous agricultural areas. At each time step, the extended Kalman filter is adopted measure and to predict the agricultural parameters including the soil moisture and temperature so that the noise associated with noisy measurements is filtered.	2019
Jun Li	Implemented the application of electric agricultural machinery, the SOC estimation of Ni-MH power batteries by the Square-Root Central Difference Kalman Filter (CDKF) approach in this paper.	2011
Esposti	Applied a Kalman filter In order to identify real long-run technological change, to a stochastic process depicting the generation of technical change induced by R&D and Extension expenditure. The empirical evidence reveals that short-term shocks greatly affect the traditional measure of productivity.	2000
Bolivar	Design, implementation and validation of two high-precision geolocation algorithms for a land vehicle from the University of Ibagué, to be used inprecision agriculture, which integrate a Kalman filter Assembled with an Adaptive Kalman filter and a conventional Kalman filter	2018
Rodríguez	Described three different implementations of the Kalman filter, using different sensor combinations but based on the same vehicle model. The alternative solution presented is to combine the data provided by different positioning sensors using a Kalman filter. The described procedure also uses an odometric estimation of the mobile position, based on the kinematic model of the agricultural vehicle	2009
Zhang	Developed an automatic guidance system on KUBOTA SPU-68 rice transplanter using Trimble 5700 RTK-DGPS and Crossbow AH RS500GA-227.RTKDGPS positioning data was corrected using the heading,roll and pitch parameters acquired from AHRS500GA.A Kalman filter based on position-velocity model was developed to smooth the corrected DGPS positioning data and evaluate the bias error of the heading angle.	2009
Gomez	Analyze the cyclical interdependence of GDPof the province of Cauca with its neighbors Nariño, Huila, Valle and Tolima Under the methodology of the Filter of Kalman and Hodrick-Prescott	2011
F. Zhang	Constructed a position-velocity (PV) model and a multi-sensor system, consisted of a consumer application GPS, a MEMS gyro, two encoders, and a turning angle sensor, for the positioning system. Was used the Kalman filter and this improves the positioning system.	2012
Lopez-Cruz	Investigated a data assimilation approach using two non-linear Kalman filters in light of prediction uncertainty. An extended EKF) and an unscented (UKF) Kalman filters were designed to estimate climate states, and also both the states and model parameters.	2015

it. Later the filter is implemented and finally the performance of the filter is measured by means of the integral of the quadratic error, in which the difference of the real states minus the states estimated by the filter is taken.Gonzalez [18]. Proposed the implementation of the Discrete Kalman Filter (DKF) algorithm together with an autoregressive model with exogenous input (ARX) to perform the forecast of short-term flows 24, 48, 72 and 96 hours in advance in the Turbio river basin, located in the state of Guanajuato and part of the state of Jalisco, Mexico, vulnerable to flooding during the periods of rain that normally occur in the area.Castillo [19] made the forecast of the drought indices SPI (Standard Precipitation Index) and SPEI (Standard Precipitation Evapotranspiration Index) for 14 meteorological stations of the Fuerte river basin in Northwest Mexico. The hypothesis was that such a goal can be achieved by implementing the Discrete Kalman Filter (DKF) algorithm.Morales [20] evaluates the utility and applicability of the discrete Kalman filter algorithm in predicting short-term flows [21-40]. The algorithm is applied to the basin of the Ángel Albino Corzo dam (Peñitas), part of the Grijalva Hydroelectric System, and to the Sayula hydrometric station [41-50].

Discussion and Conclusion

From the reviews carried out in articles from other countries, the use of this method in navigation systems is notoriously important. In Mexico, as this field is incipient, the application of the Kalman filter is also used for other types of research such as irrigation, agricultural economics agrometereology and models of crop growth as researchers focus on more current topics such as aerial and land unmanned agricultural vehicles the use of this important tool will also be greatly increased due to its benefits and applications in navigation [51-60].

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Page 5/5