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Presentation of the content

In the first article we present *Calculating tool for power factor and compensating vectorial capacitors on inductive charges* by VILLA-AVIÑA, Sergio Alejandro, VILLALVAZO-LAUREANO, Efrain, ROSALES-BUSQUETS, Enrique Carlos and GONZÁLEZ-LÓPEZ, Juan Miguel with adscription in the Universidad de Colima, in the next article we present *Synchronization of active systems in material handling processes* by RODRÍGUEZ-FRANCO, Martín Eduardo, JARA-RUIZ, Ricardo, LÓPEZ-ÁLVAREZ, Yadira Fabiola and MARTÍNEZ-MARTÍNEZ, Malinali Xochiquetzal with adscription in the Universidad Tecnológica del Norte de Aguascalientes in the next article we present *Implementation of the RCM methodology in pleating machine* by TUDÓN-MARTÍNEZ, Alberto, ZUÑIGA-MARTINEZ, Marco Antonio, LERMA-GARCÍA, Miguel Angel and MÉNDEZ-GOVEA, Luis Alberto with adscription in the Universidad Tecnológica de San Luis Potosí, in the next article we present *Change points in space-time, methodology and applications* by MUÑIZ-MERINO, Lucila, JUÁREZ-HERNANDEZ, Bulmaro and CRUZ-SUARES, Hugo Adan with adscription in the Benemérita Universidad Autónoma de Puebla.

Content

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Calculating tool for power factor and compensating vectorial capacitors on inductive charges

Herramienta para el cálculo del factor de potencia y capacitores compensadores vectoriales en cargas inductivas

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Abstract

In the present work, a power factor (PF) calculation tool for single-phase electric networks is shown. This tool is made in Matlab and Simulink; it contains several useful functions such as the condenser code to achieve the desired result, from the measured value to the unit. It is also possible to visualize the voltage and current phase shift when the system is in the compensation system and its decrease as the PF approaches the unit. On the other hand, it is worth noting the decrease in current by the increase of the PF or compensation. All benefits can be seen graphically for a better understanding of possible compensation solutions.

Power factor, Vector, Element, Current

Resumen

En el presente artículo se muestra una herramienta para el cálculo del factor de potencia (FP) para redes eléctricas monofásicas. Esta herramienta esta elaborada en Matlab y Simulink; contiene varias prestaciones útiles como el cáclulo del capacitor para lograr el FP deseado, desde el valor medido hasta la unidad. Además, se puede visualizar claramente el desfasamiento del voltaje y la corriente cuando el sistema se encuetra sin ningún tipo de compesación y la disminución de este conforme el FP se va acercando a la unidad. Por otra parte, y una de las más importantes es la disminución de la corriente al incrementar el FP o la compensación. Todos los beneficios se pueden ver en forma gráfica para una mayor comprensión de las posibles soluciones de compensación.

Factor de potencia, Vector, Elemento, Corriente

Citation: VILLA-AVIÑA, Sergio Alejandro, VILLALVAZO-LAUREANO, Efrain, ROSALES-BUSQUETS, Enrique Carlos and GONZÁLEZ-LÓPEZ, Juan Miguel. Calculating tool for power factor and compensating vectorial capacitors on inductive charges. Journal of Quantitative and Statistical Analysis. 2019 6-19: 1-5

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Introduction

Demanding a greater amount of reactive power will result in a poorer power factor, due to unnecessary high currents with large losses and voltage drops. Consequently, consumers are penalized for the utility of the power factor. The installation of a capacitor bank, the power of which corresponds to the nominal load, decreases the value of the input current without causing overvoltages in the load (Joksimovic, 2015).

Nowadays it is very important and an urgent need to improve the energy quality and efficiency of the electrical system; for that there are active solutions for the PFC (Power Factor Correction) (Pinheiro, 2012).

One article mentions that the boost power factor correction (PFC) converter is a popular choice due to its known dynamics and simplicity, actively controlling the current of the AC line, to be sinusoidal and in phase with the AC (alternating current), line voltage ACV (alternating current voltage), commonly known as PFC (Clark, Musavi, & Eberle, 2014).

One of the purposes of the use of tools and techniques for PFC is to maintain the load side voltage in a sine wave form, which is essential for the safe and efficient operation of critical loads (Jian Ye, 2019).

The PFC plays an essential role in eliminating power losses. A PFC places the input current in phase with input voltage waveforms. When the power factor is 1.0, the input current is perfectly in phase with the input voltage (R. Meendevi, 2017).

Working with the application of devices for power factor correction is paramount to obtain the benefits that are specified as:

- Reduction of losses in conductors.
- Reduction of voltage drops.
- Increased power availability of transformers, lines and generators.
- Increase of the lifespan of facilities.

And, on the other hand, the economic gains showed below:

- Reduction of costs for electric billing.
- Elimination of rates due to low power factor.
- Bonus of up to 2.5% of billings when there is a power factor greater than 0.9.

In general, the power factor in a 24-hour period is below 0.9, which consumes a large amount of additional energy and, in turn, is penalized by electric power companies (Ke Wang, 2017).

In addition, taking into account that in Mexico the prices of electric power consumption are variable, according to the amount of power taken from the power grid and the average annual temperature, it is very important to have a power factor as close as possible to the unit, to avoid excessive costs of unused electricity. The rates are detailed in table 1.

Rate	1	1A	1B	1C	1D	1E	1F
Thousands of pesos	0.25	0.3	0.4	0.85	1	2	2.5

Table 1 Consumption rates (CFE, 2019)

The data in the table clearly shows the importance of not exceeding the consumption from what is indicated; in addition, consumption lower than the one marked by the rates of the Federal Electricity Commission (CFE) is subsidized by the government in Mexico.

Program for vector calculation

It has always been important to have a power factor close to the unit; however, it is necessary to ensure that all types of electrical systems comply with this requirement as much as possible, but taking into account that the system should not resonate for it can oscillate, causing the power grid to fail. For this purpose, a tool was developed in Matlab with the aim of allowing anyone who has this tool to calculate the necessary compensation for the desired PF; in addition to dynamically observing the behavior of the equivalent power grid.

The first thing that has to be done is to feed the system with real values; preferably obtained with a reliable energy quality meter, the requested data are those shown in the following lines of code:

```
clc
clear
v=128.6 ;%Measured voltage of the system.
f=60; %Line frequency.
I=14; %Measured rms current, without compensation.
fp=0.24; % System power factor.
```

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Subsequently to have the possibility of making a calculation from 0.24 with increments of 0.01 until reaching 1 of the PF value; this is done by declaring a vector, similarly it is done to obtain resistance, capacitance, inductance and power. This can be seen in the part of the code below.

```
theta=acos(fp);
m=fp:.01:1; % Power factor vector for capacitor
calculation.
[r1 c1]=size(m);
c= zeros(size(m)); %. Vector for capacitor results of
the same size as the previous vector.
l=((v/I)*sin(theta))/(pi*2*f);%Calculation of the
inductance that occurs with the conditions described.
r=(v/I)*cos(theta); %Calculation of resistance
according to the previous conditions.
p=v*I*cos(theta); %vrms*irms*fp=P,
```

Subsequently, all desired values were calculated, emphasizing that all these data must be based on real values measured in a single phase electrical system. The computation of the data is observed in the following lines of code.

```
for n=1:1:c1
fpd=m(n); % Desired power factor.
thetad=acos(fpd); % Desired angle.
Id=I*cos(theta)/cos(thetad); %Irms*cos(theta) by
cos(desired theta).
Ic=I*sin(theta)-Id*sin(thetad); %capacitor current.
c(n)=Ic/(2*pi*f*v); %Capacitor.
End
```

Another feature of the tool is the visualization of the data in graphic form of a fair spectrum of power factor values, together with corresponding capacitance values, according to the required value of the power factor.

For the particular case of *v*=128.6 volts, *f*=60 Hz, *I*=14A and a *pf*=0.24; however, Figure 1 shows a large number of values together with the capacitance value corresponding to the PF value, although the resulting graphs will always start from the measured PF value.

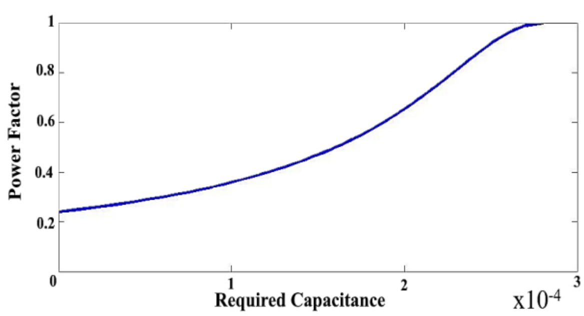

Figure 1 PF measured from 0.24 with capacitance

In order to verify the value of the PF at any of the points on the graph, a diagram was made in Simulink. The capacitance is related in vector form to the Matlab calculation; in the case of the example, it starts from 0.24 with increments of 0.01 to 1. This results in 77 different capacitance values, in which the value number 77 is the one corresponding to the result of a PF equal to 1. The corresponding diagram is shown in Figure 2.

Diagram for graphical display of power factor variables

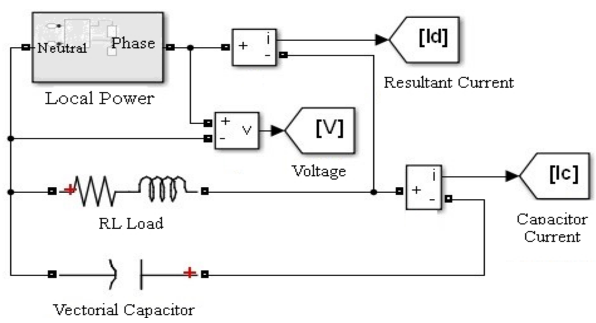

Figure 2 Diagram with vector capacitor

After a simulation of two seconds and placing the number 77 element in the vector capacitor, the result is the PF of the line shown in the green graph, as well as its comparison with the original PF which is observed in blue. These results are shown in figure 3.

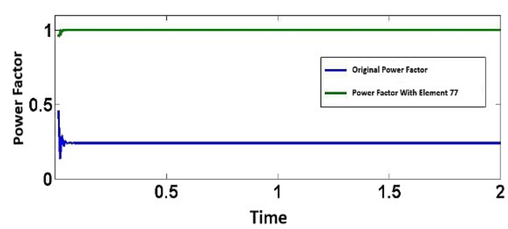

Figure 3 Power factor with element 77

The graphic result with the calculation of element 75 is exemplified in Figure 4, which is further from the ideal PF that is 1. It should also be noted that calculating an ideal PF could cause the power grid to come into resonance because in practice all the elements have both positive and negative tolerances.

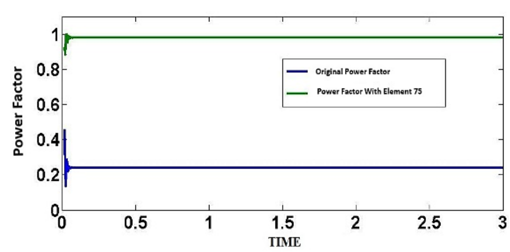

Figure 4 Power factor with element 75

Next, we present a program starting from a measured PF of 0.5, in which the vector will only contain 51 elements, the lines are represented in the following code and the compensation graph in figure 5.

```
clc
clear
v=128.6 ;%Measured voltage of the system.
f=60; %Line frequency.
I=14; %Measured rms current, without
compensation.
fp=0.5; %System power factor.
```

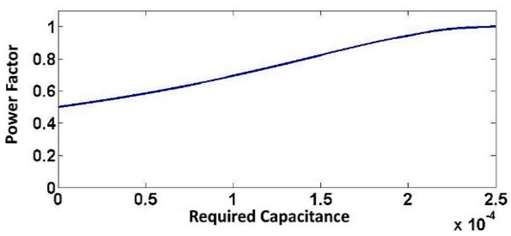

Figure 5 PF measured of 50 with capacitance

This tool also displays the phase shift between current and voltage; first with the power factor measured as shown in figure 6 and then with the PF in the desired element according to the initial values, for element 76 with initial PF of 0.24 is represented in figure 7.

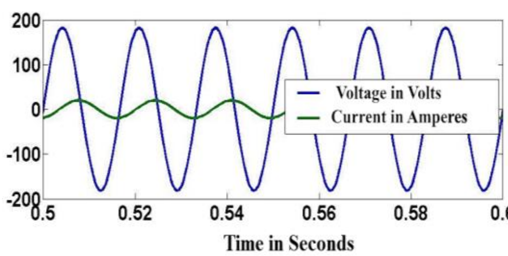

Figure 6 Phase shift with measured FP of 0.24

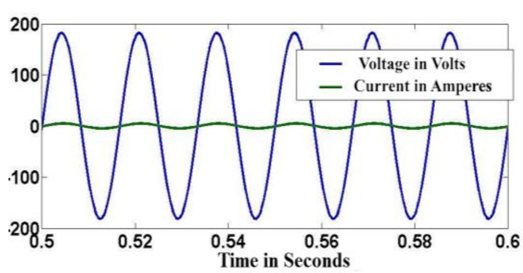

Figure 7 Phase shift with FP with element 76

Something that can be distinguished with this tool is the proximity to the resonance of the system; when the power factor is in the ideal zone or equal to 1, this happens with the vector capacitor in the value 77, as shown in figure 8. It should be mentioned that the measured current was increased up to 60 A for this.

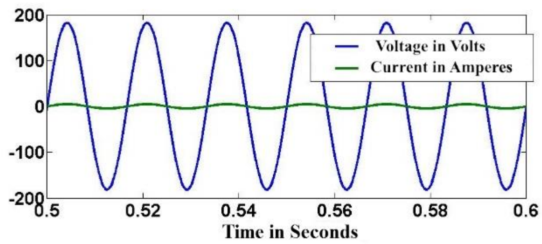

Figure 8 Phase shift with FP with element 77

Finally, another benefit of the tool is the clear understanding of the amount of the system current without compensating as distinguished in Figure 9 and its notable decrease when applying compensation with element 77 of the vector, in Figure 10.

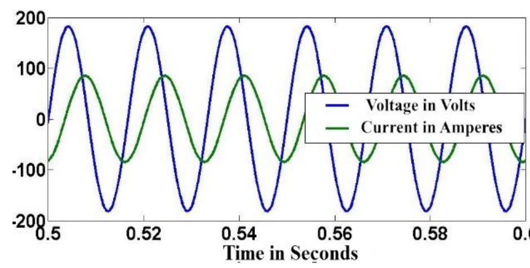

Figure 9 Phase shift with measured current of 60A and without compensation

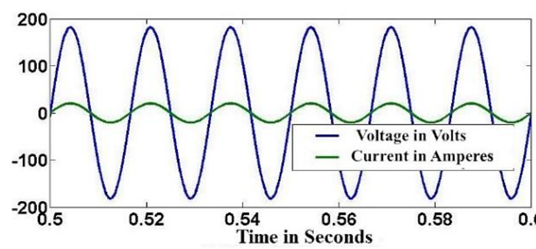

Figure 10 Phase shift with measured current of 60A and with compensation

Acknowledgments

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Conclusions

It is a tool that can help anyone understand the dynamic behavior of the PF according to the compensation that is desired in any single-phase electrical network.

Visualization of the current and voltage phase shift is rather simple depending on the power factor; in addition to giving the convenience to observe the voltage and current signals before and after compensation.

It can compare the original PF and the one that originates after placing the compensatory capacitance.

It is a tool that can be coupled or modified with great ease, according to the requirements of the power grid to be analyzed.

Finally, it is very simple to use, this is because it takes little time to acquire full knowledge of the tool.

References

CFE. (09 de Julio de 2019). Comisión Federal de Electricidad. Retrieved from https://app.cfe.mx/Aplicaciones/CCFE/Tarifas/TarifasCRECasa/Tarifas/TarifaDAC.aspx

Clark, C. W., Musavi, F., & Eberle, W. (2014). Digital DCM Detection and Mixed Conduction Mode Converters. IEEE Transactions on Power Electronics, 347 - 355.

Jian Ye, H. B. (2019). Elliptical restoration based single-phase dynamic voltage restorer for sourcepower factor correction. Electric Power Systems Research, 199-209.

Joksimovic, G. (2015). Transformer Reactive Power Compensation–Fixed Capacitor Bank Calculation. IEEE TRANSACTIONS ON POWER DELIVERY, 1629.

Ke Wang, H. H. (2017). Study on Power Factor Behavior in High-Speed Railways. IEEE Transactions on Transportation Electrification, 1 to 11.

Pinheiro, L. R. (2012). Digital current controllers applied to the boost power factor correction converter with load variation. IET Power Electronics, 532-541.

R. Meendevi, L. P. (2017). A Novel bridgeless SEPIC Converter for Power Factor Correction. 1st International Conference on Power Engineering, Computing and CONtrol, 991-998.

Sujata Powniker, S. S. (2016). Development of Active Power Factor Correction. IEEE International WIE Conference on Electrical and Computer Engineering (WIECON-ECE), 212-216.

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Synchronization of active systems in material handling processes

Sincronización de sistemas activos en procesos de manejo de materiales

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Abstract

The present work proposes an application of automata's language and control systems in discrete events theory in a prototype of material handling system to ensure the continuity in the sequence that a transferred piece will have to execute between two points of a productive process. Also guaranteeing the synchronization of its active elements, in this case, a robot in angular configuration and a conveyor belt, for the fulfillment of its specific task without errors. We describe the development of the prototype for testing, the programming of the digital process controllers based on the theoretical methodology suggested, and finally, the integration of a graphical monitoring and control interface that allows the visualization of the system state to the user. The results suggest the adequate performance of the developed algorithms, the graphical interface and, in general, of the active elements that make up the material handling system.

Synchronization, Active system, Material handling

Resumen

El presente trabajo propone una aplicación de lenguaje de autómatas y de la teoría de sistemas de control en eventos discretos en un prototipo de sistema de manejo de materiales, para asegurar la continuidad en la secuencia que habrá de ejecutar una pieza trasladada entre dos puntos de un proceso productivo. Garantizando, además, la sincronización de sus elementos activos, en este caso un robot en configuración angular y una banda transportadora, para el cumplimiento de su tarea específica sin errores. Se describe el desarrollo del prototipo para prueba, la programación de los controladores digitales de proceso a partir de la metodología teórica sugerida, y finalmente, la integración de una interfaz gráfica de monitoreo y control que permita la visualización del estado del sistema hacia el usuario. Los resultados sugieren el adecuado desempeño de los algoritmos desarrollados, la interfaz gráfica y, en general de los elementos activos que integran al sistema de manejo de materiales.

Sincronización, Sistema activo, Manejo de materiales,

Citation: RODRÍGUEZ-FRANCO, Martín Eduardo, JARA-RUIZ, Ricardo, LÓPEZ-ÁLVAREZ, Yadira Fabiola and MARTÍNEZ-MARTÍNEZ, Malinali Xochiquetzal. Synchronization of active systems in material handling processes. Journal of Quantitative and Statistical Analysis. 2019 6-19: 6-12

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Introduction

The synchronization of active systems or elements within current manufacturing systems, such as manipulator robots and conveyor belts, promotes the organization of activities (Huang, 2015), resulting in the optimization of human and material resources, as well as in the improvement of the time required for the execution of general tasks (Ore, Hansson & Magnus, 2017). Therefore, such specification must ensure at all times that each element fulfills the function for which it has been considered within the process.

In turn, a set of multiple organized active elements and with a defined sequence of action determine the integration of material handling systems (Björnsson, Jonsson & Johansen, 2018), underpinning the internal logistics of a company, by providing the guide of raw and transition materials or elaborated product, from one section to another within the production process, as well as the distribution that the latter will acquire. Thus, the implementation of the type of system, as well as the components that will be used, may vary depending on the needs of the process in which it is applied.

This paper presents the development and integration of a prototype of material handling system in order to analyze the effect of the application of formal techniques of the automaton and control systems in discrete events theories, for the assurance of synchronization and sequence in transportation tasks, recovery and positioning of parts (Santos-Gomes & Rodrigues-Leta, 2012) (Kumar, et al., 2014) between active elements of a typical manufacturing process. In addition to adapting an interface for monitoring and control of such a system with the LabVIEW software in communication with an electronic card that serves as a process controller (Koniar, et al., 2014).

Background

The knowledge of the conditions to perform an adequate synchronization between the functions of two or more active elements within a material handling system responds commonly to the experience of the person in charge of its planning and to their total understanding of the behavior of the devices involved, which can mean a tedious task of not having the necessary preparation.

Synchronization is based on the full identification of all the signals that converge within the manufacturing process in which it is implemented. However, its use must adopt a systematized form to achieve the objective of the intervened activity, in this case, transportation of materials without duplication of tasks or inactive times; and, if it is translated into a specific language, it can be introduced to the process controller for proper management.

The challenge proposed for this research is the application of a formal methodology, based on mathematical language, for the synchronization of physical operations; in order to provide a support tool for the optimal organization of the tasks to be executed by each active element that constitutes a material handling and positioning system within a given manufacturing process. The above will be implemented through the integration of a simple prototype for testing.

Constitution of the testing prototype

The prototype consisted of a robot in angular configuration with a gripper mounted on its final effector as a work tool, as well as a conveyor belt to which infrared sensors were included at its ends. It should be mentioned that the ends of the band used within the robot's work area were secured, enabling it to reach and adopt the positions. Two areas were also defined within the work area, corresponding to the material supply for process and storage once the proposed transport and positioning sequence was completed. The elements mentioned are shown in Figure 1.

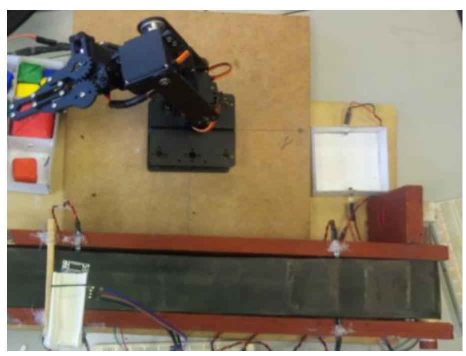

Figure 1 Physical distribution of the prototype
Source: Prepared by the authors, 2019

The robot is made up of three links and three joints, allowing movement to enter the structure to place the end of it in any desired position within its work area.

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The band has been implemented from a cycle belt of synthetic material, at the ends of which is supported by two rollers, one of them attached to a direct current motor that induces movement to the system. The supply is done manually, considering, in this case, pieces with the same dimensional specification 3x3x3 cm, since the robot's gripper was conditioned to close with this particular thickness.

Signal definition and process sequence

The interacting signals within the developed process can be categorized as parameters if they are inputs, or alternatively, variables if they are outputs. According to the type of signal given, these are discrete parameters and variables since they can only acquire certain values within a set range, commonly: activation or deactivation, or a pulse trains. For this analysis, the parameters come from sensors and buttons the function of which is binary. The processing of the parameters favors the generation of the variables that can take an on or off value, as is the case with the band, or use a pulse train to control the servomotors which move the robot. The information of the process signals is presented in Tables 1 and 2.

Identifier	Signal	Active system
PB0	System on	General System
ZS0	Supply Sensor	General System
ZS1	End sensor 1	Conveyor belt
ZS2	End sensor 2	Conveyor belt
X0dn	In rest position	Robot
X1dn	In end position 1 in the band	Robot
X2dn	In end position 2 in the band	Robot
X3dn	In storage position	Robot
Gcldn	Closed	Gripper
Gopdn	Open	Gripper

Table 1 Process parameters
Source: Prepared by the authors, 2019

Identifier	Signal	Active system
X0	To rest position	Robot
X1	To supply position	Robot
X2	To end position 1 of the band	Robot
X3	To end position 2 of the band	Robot
X4	To storage position	Robot
X5	To rest position	Robot
Gcl	Close	Gripper
Gop	Open	Gripper
MT	Active motor	Conveyor belt

Table 2 Process Variables
Source: Prepared by the authors, 2019

The process sequence proposal is made from the signals shown above, allowing the synchronization of the active elements, as described below:

1. If the system is on and, when the piece is detected in the supply area of the prototype, the movement of the robot will be enforced to take it to a first end of the band.
2. Once the robot arrives at the first end of the conveyor belt, its operation will be activated to allocate the piece to the opposite end.
3. The robot must remain at rest for as long as the piece travels the length of the band.
4. When the piece reaches the opposite end of the band, it will stop its movement.
5. The robot will emit a movement, moving towards the opposite end of where it originally placed the piece.
6. Such element will describe a trajectory that allows it to take the piece towards the respective shortage area.

It should be noted that the initial conditions for the operation of the system are:

– The robot will start from a rest position where it will remain with the gripper open.
– There should be no piece in any part of the process.
– Once the process is executed, it will repeat its sequence indefinitely.
– There is the possibility of stopping the process at any time.
– If the process function is restored, its operation will be executed from the beginning.

Deduction of the model for synchronization

The sequence of the analyzed process can be defined from a mathematical formalism which relates the input signals of the process, the stage or state that will activate each of these, and the generation of the signals that allow the activation of the electric charges (Zhang, et al., 2012), which are part of the active elements of the prototype; with the aim of promoting their movement. Thus, in control systems of discrete events (Barkalov, Titarenko & Chmielewski, 2013) and specifically, in the theory of automatons (Ahmad, Ali & Shoba Das, 2006), the previously exposed signals, as well as their relation with each stage of the process, can be represented mathematically through the definition of a finite alphabet (1) corresponding to the input signals of the system.

E = {PB0, ZS0, ZS1, ZS2, X0dn, X1dn, X2dn, X3dn, X4dn, X5dn, Gcldn, Gopdn} (1)

In addition to requiring the declaration of a set of values that imply the different states which the system elements (2) will acquire throughout the evolution of the process sequence.

X = {0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11} (2)

Through the combination of states and transitions, specific values acquired by an input or set signal, the proposal of the functions which define the sequence (3-14) is made to be executed by the active elements of the material handling system , also ensuring synchronization between its functions.

f (0, PB0 ZS0) = {1} (3)
f (1, X1dn) = {2} (4)
f (2, Gcldn) = {3} (5)
f (3, X2dn) = {4} (6)
f (4, ZS1 Gopdn) = {5} (7)
f (5, X0dn) = {6} (8)
f (6, ZS2) = {7} (9)
f (7, X3dn) = {8} (10)
f (8, Gcldn) = {9} (11)
f (9, X4dn) = {10} (12)
f (10, Gopdn) = {11} (13)
f (11, X0dn) = {0} (14)

The establishment of the initial (15) and final (16) states within the process sequence allows the conclusion of the model that defines it.

x0 = {0} (15)
F = {0} (16)

After interpreting the numerical outputs to the states that the system will have to adopt in a real form, a set of the corresponding physical outputs is generated, defined by (17).

X = {X0, X1, Gcl, X2, Gop, X0, MT, X3, Gcl, X4, Gop, X0} (17)

The concentration of the data specified in a functional scheme, still represented in a symbolic way, allows the analysis of the input and output signals of the process and the visualization of the activation of the necessary stages exclusively at the time it is required, ensuring at all times the action of the different states in the active systems and, therefore, the proper sequence of the process.

Programming of the control system

The adequate fulfillment of the proposed tasks to be executed by the prototype and its general operation will depend on the correct selection, programming and use of process controllers. In this case, two Arduino UNO electronic cards are used to carry out these activities. A scheme of the interaction between the controller cards, the sensors, the process control and monitoring interface, and the active elements of the prototype are shown in Figure 2.

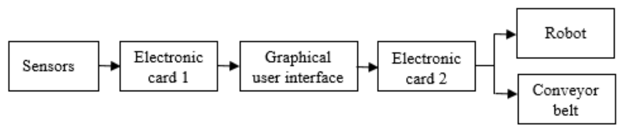

Figure 2 Interaction between prototype components
Source: Prepared by the authors, 2019

It is clear the use of a first card as an element to collect information from buttons and sensors used as a means of knowing the work environment of the prototype. To a second card are connected, using the appropriate power management means, the actuators that will allow the transmission of movement both to the robot's joints and to the band itself.

Both cards remain in communication with a computer through two USB ports and the serial communication protocol. Therefore, it will correspond to the latter to contain the program that performs the management of the process executed by the prototype and ensure the succession of the states which must be addressed. The main concern in developing such a program was to provide accessibility and easy handling to the users, informing them at all times of the evolution of the system states from the signals derived from the input devices.

Management Interface Development

Since most of the actions are performed automatically, the control and monitoring interface developed from a virtual instrument in the LabVIEW software (as shown in Figure 3), presents an information environment to the system user, which enables feedback on the state of the managed system (Gasparic, et al., 2017).

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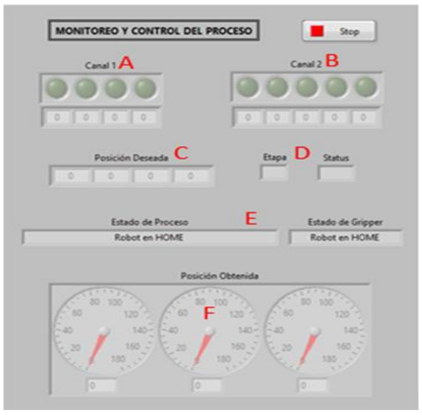

Figure 3 Interface developed for process control and monitoring
Source: Prepared by the authors, 2019

For this, such an interface can be divided in various areas according to the information presented:

a. Information that the process controller will issue as output for the activation of active systems.
b. Status of the process inputs, allowing the detonation of a specific task by the system.
c. Information of the angular position that the controller sends to each of the articular coordinates.
d. Alphabetical references of the state of the process and the particular state of the robot's gripper.
e. Complementary message that alerts the user of the current state of the process, indicating the location of the robot, and the status of the band and the gripper.
f. Feedback of the articular variables of the robot as the controller orders the modification in the Cartesian position of the robot.

However, giving the user the possibility of modifying the position that the robot's gripper can reach according to the progress of the process sequence, involved the addition, to the developed interface, of a section that allowed the entry of strategic points that would lead to the evolution of the movement from an initial position to a different one within its area of action. Of course, to limit the occurrence of collisions between active systems, it is necessary for the user to propose a series of movements considering the physical location of the robot and its gripper, specifically with respect to the band and the location of the sensors, in order not to cause involuntary damage during the execution of movement.

The enabled spaces allow the placement of the values which the joint variables must assume as they carry out an evolution, ensuring the recovery and positioning of any object present at some point in the process and its destination to another position, without jeopardizing the integrity of any element. As well as to make an adequate combination between effective positions to reach the pieces and the state that the gripper must assume, depending on the case.

For example, when executing a movement for the collection of a piece, it will be necessary to pre-open the gripper and quickly position it on the object, ensuring that it is in a position just in the center of the opening margin, and continue with a movement of the final effector at a point of lower height, which favors the holding of the piece. Such a case may also operate in reverse, that is, when placing an object in a given location, it will be necessary to choose a timely position that allows its release and thus guarantee the sequence of the executed process.

Results of the system operation

The response generated by the graphical interface was favorable at issuing at all times the information related to the current state of the process and its evolution as the succession of tasks was executed. Such information, of course, coincided with the real state adopted by the active elements of the physical prototype, which can be corroborated in the evidence presented by the following figures. The sequence proposed for the prototype implemented was performed correctly, according to the organization proposed in the mathematical model of the process (1-17), clearly prescribing each of the indicated transitions from the corresponding input signals.

Figure 4 reports the robot's resting position waiting to begin the execution process of the material handling system. So, as determined from the beginning of this work, when energizing the system this will be the position that the robot will adopt by default.

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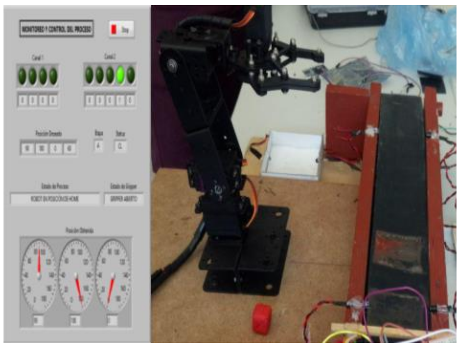

Figure 4 Resting robot.
Source: Prepared by the authors, 2019

Highlighting the opening state in the gripper during the adoption of this last position. Figure 5 shows the evolution of the robot's movement when the system has detected a piece in its supply area, immediately allocating the robot's gripper to reach the object and perform its holding.

Figure 5 Robot in supply area
Source: Prepared by the authors, 2019

In the figure below it can be seen that the robot makes the placement of the piece on the first end of the conveyor belt, which will be activated by allocating it towards its opposite end.

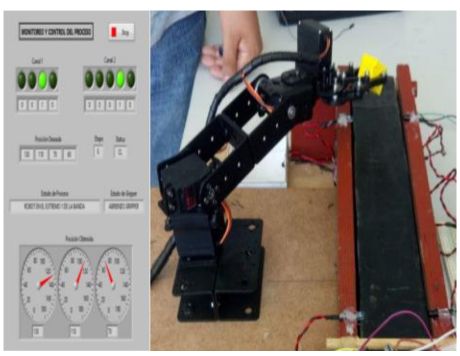

Figure 6 Robot on first end of the band
Source: Prepared by the authors, 2019

Precisely at the other end of the band, the robot is guided to hold the piece in this last position, as shown in figure 7, and allocate it to the corresponding shortage area.

Figure 7 Recovery of piece on the second end of the band
Source: Prepared by the authors, 2019

The results of the final arrangement of the piece according to the executed sequence are presented in Figure 8.

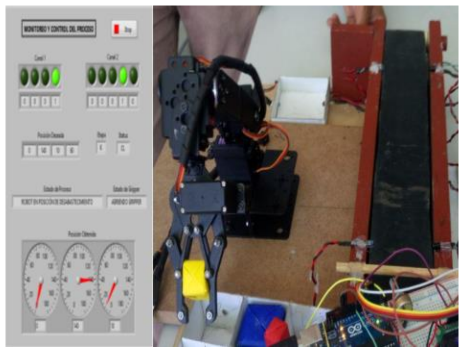

Figure 8 Robot in shortage area
Source: Prepared by the authors, 2019

Conclusions

The internal logistics of a company focuses on the proposal of an adequate distribution of the material handling system and the sequence that must be executed to supply the work stations, as required by the production process. Therefore, the adoption of formal methodologies and their application in the planning of transport activities, recovery and positioning of pieces directly leads to assurance in their succession.

However, the success of the sequence of actions to drive the products from one point or another will depend on the adequate definition of the states, the transitions that will allow going from one state to another, the knowledge of an initial condition of the system and the objective proposal of its final situation.

In this case, the foundations of the theory of control systems in discrete events and, in particular, of automaton, allowed us to deduce a mathematical model of the process; which was translated into the programming algorithms required on specific digital controllers, such as the Arduino electronic cards employed.

This control system, in direct communication with a computer graphic interface, allowed the total management of the actions performed within the process; which enabled the synchronization of the active elements, the robot and the conveyor belt.

Although the experimentation was developed from a physical prototype of simple constitution the implements of which imply the provision of more robust equipment, it was possible to characterize the programming behavior of a sequence proposed at the beginning of the analysis. The above, makes possible the complementation of the function achieved by the integrated material handling system with the addition of some other element that allows the flexibility of the process, determining the continuity of this work.

References

Ahmad, I., Ali, F. M., & Shoba Das, A. (2006). Synthesis of finite state machines for improved state verification. *Computers & Electrical Engineering*, 349-363.

Barkalov, A., Titarenko, L., & Chmielewski, S. (2013). Synthesis of Moore finite state machines based on pseudoequivalent states. *IFAC Proceedings Volumes*, 233-238.

Björnsson, A., Jonsson, M., & Johansen, K. (2018). Automated material handling in composite manufacturing using pick-and-place systems - a review. *Robotics and Computer-Integrated Manufacturing*, 222-239.

Gasparic, M., et al. (2017). A graphical user interface for presenting integrated development environment command recommendations: Design, evaluation, and implementation. *Information and Software Technology*, 236-255.

Huang, Y. (2015). Robust multi-robot coordination in pick-and-place tasks based on part-dispatching rules. *Robotics and Autonomous Systems*, 70-83.

Koniar, D., et al. (2014). Virtual instrumentation for visual inspection in mechatronic applications. *Procedia Engineering*, 227-234.

Kumar, R., et al. (2014). Object detection and recognition for a pick and place robot. *Asia-Pacific World Congress on Computer Science and Engineering*, 1-7.

Ore, F., Hansson, L., & Magnus, W. (2017). Method for design of human-industrial robot collaboration workstations. *Procedia Manufacturing*, 4-12.

Santos-Gomes, J. F., & Rodrigues-Leta, F. (2012). Aplications of computer vision techniques in the agriculture and food industry: a review. *European Food Research and Technology*, 989-1000.

Zhang, X., et al. (2012). A study on the extended unique input/output sequence. *Information Sciences*, 44-58.

Implementation of the RCM methodology in pleating machine

Implementación de la metodología RCM en máquina plisadora

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Abstract

The objective of this project is to reduce the downtime of a machine that performs the pleating of materials in a company dedicated to the manufacture of automotive parts. The development of this project aims to increase the availability of the machine and contribute to the use of material and humnan resources, achieving an increase in production to ensure permanence and competitiveness in the Market. Reliability Centered Maintenance (RCM) will be the methodology used to achieve the goal. The implementation of this methodology contributes to the updating of maintenance programs to achieve an increase of the MTBF indicator (Average Time Between Failures) and the decrease of the MTTR (Mean Time to Repair). The application of maintenance methodologies that exist today plays an important role within the industrial sector when it is necessary to meet the goals set by companies to meet the needs of customers.

Maintenance, Reliability, Machine

Resumen

El objetivo del presente proyecto es la disminución de los tiempos improductivos de una máquina que realiza el plisado de materiales en una empresa dedicada a la fabricación de piezas automotrices. Con el desarrollo del presente proyecto se pretende incrementar la disponibilidad de la máquina y contribuir al aprovechamiento de los recursos materiales y humnanos, logrando un incremento en la producción para garantizar la permanencia y la competitividad en el mercado. El Mantenimeinto centrado en la confiabilidad (RCM) será la metodología que se utilizara para el logro del objetivo. (Falcon, 2015). Con la implementación de esta metodología se contribuye a la actualización de los programas de mantenimento para lograr un incremente del indicador MTBF (Tiempo promedio entre falla) y el decremento del indicador MTTR Tiempo promedio de reparación). (Villanueva E. D., 2014). La aplicación de las metodologías de mantenimiento existes en la actualidad juegan un papel importante dentro del sector industrial cuando se requiere cumplir con las metas establecidas por las empresas para satisfacer las necesidades de los clientes.

Mantenimiento, Confiabilidad, Máquina

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Introduction

Companies are in constant need of improving the availability of equipment by reducing downtime, contributing to increased productivity and the offering of products at competitive prices in the market.

The increase of unproductive times in the material pleating machine was detected in the second half of 2018, which presented a decrease in availability directly affecting productivity.

The tools used are the RCM methodology (Reliability Centered Maintenance), the analysis of the machine's fault history and the revision of the current state of the preventive, predictive and autonomous maintenance program. (Garcia, 2015)

The project hypothesis is that increasing the MTBF maintenance indicator and reducing the MTTR maintenance indicator will reduce the downtime of the pleating machine and this will contribute to the increase in production.

Method Description

The problem is addressed through the RCM methodology, Reliability Centered Maintenance, based on failure analysis (Martín, 1998).

Both, failures which have already occurred and those which have a certain probability of occurring and carry serious consequences are analyzed. During the analysis process, six key questions must be answered for each of the systems that make up the plant:

1. What are the functions and operating standards in each system?
2. How does each device and each system as a whole fail?
3. What is the cause of each failure?
4. What consequences does each failure have?
5. How can each failure be avoided?
6. What should be done if it is not possible to avoid a failure? (Falcon, 2015)

Methodology development

Figure 1 shows the RCM methodology, which consists of a series of phases for each of the systems that make up the machine.

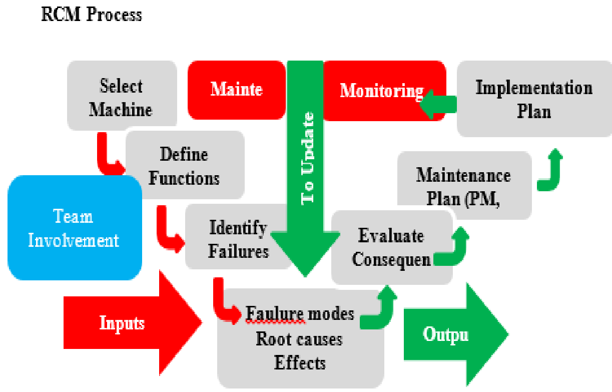

Figure 1 RCM methodology process
Source: Project contribution, unpublished

Phase 0: Coding and listing of all subsystems, equipment and elements that make up the system. Compilation of schemes, functional diagrams, logical diagrams, etc.

No.	System.
1	Pleating system.
No.	**System.**
2	Unwind system.
3	Tension system.
4	Heat iron.
5	Marking system

Table 1 Subsystem List
Source: Project contribution, unpublished

Phase 1: Detailed study of the system operation. List of system functions as a whole. List of functions of each subsystem and of each significant equipment integrated in each subsystem.

No.	System.	Main function.
1	Pleating system.	Pleating paper and mesh.
No.	**System.**	**Complementary functions.**
2	Unwind system.	Unwinding paper and mesh.
3	Tension system.	Applying tension to paper and mesh.
4	Heat iron.	Treating glue.
5	Marking system.	Marking the pleat (red or blue).

Table 2 List of main and complementary functions
Source: Project contribution, unpublished

Phase 2: Determination of functional and potential failures.

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Main function	Functional failures
Pleating paper and mesh.	1. Does not pleat paper and mesh.
	2. Partially pleats paper and mesh.
Secondary Functions	**Potential failures**
Unwinding paper and mesh.	3. Does not unwind paper and mesh.
	4. Partially unwinds paper and mesh.
Applying tension to paper and mesh.	5. Does not apply tension topaper and mesh.
	6. Partially applies tension to paper and mesh.
Treating glue.	7. Does not treat glue.
Marking the pleat.	8. Does not mark the pleat.
	9. Partially marks the pleat.

Table 3 List of functional and potential failures
Source: Project contribution, unpublished

Phase 3: Determination of the failure modes or causes of each of the failures found in the previous phase.

Functional failures.	Mode of Failure	Root Cause
1. Does not pleat paper and mesh.	- The turbine does not start and the andon alarm is fired.	Stuck turbine motor bearings
2. Partially pleats paper and mesh.		Hit mesh detection sensor
Potential failures.		
3. Does not unwind paper and mesh.	- The pleat comes out fluorescent (short and long).	Broken voltage sensor internal sheet
4. Partially unwinds paper and mesh.	- Paper comes out without secondary mesh.	Hit mesh sensor.
5. Does not apply tension topaper and mesh.	- The pleat comes out fluorescent (short and long). - Unwind paper and mesh.	Broken tension sensor internal sheet
6. Partially applies tension to paper and mesh.	- The paper breaks and the sliding rollers skid.	Loose transmission serrated band
7. Does not treat glue.	- The mesh does not stick to the paper	Open resistors.
8. Does not mark the pleat.	- It does not have the mark color on the pleat (Red or blue).	Blocked marking gun.
9. Partially marks the pleat.	- Stains the entire pleat with paint.	Worn marking gun seals.

Table 4 Failure modes and root cause.
Source: Project contribution, unpublished

Phase 4: Study of the consequences of each failure mode. Classification of failures in critical, important or tolerable according to consequences.

Root Cause	Frequency	Severty	Detection	Security	Cost	Total
Stuck turbine motor bearings	1	1	2	1	2	4
Open fuses.	2	1	4	1	1	8
Damaged emergency brakes (Open)	2	1	4	2	1	16
Hit mesh sensor	2	2	4	1	2	32
Dirty safety curtains	2	1	1	1	1	2
Transducer alignment mechanism stained with glue	2	1	1	1	2	4
Flamed safety relays.	1	1	4	2	2	16
Lack of pressure in rollers	2	2	3	1	1	12

Table 5 Consequence Evaluation
Source: Project contribution, unpublished

Phase 5: Determination of preventive measures that avoid or mitigate the effects of failures

Root Cause	Maintenance Activities
Stuck turbine motor bearings	Replace bearings
Open fuses.	Replace fuses.
Damaged emergency brakes (Open)	Repair emergency brakes or replace them.
Hit inductive mesh detection sensor	Replace inductive sensor.
Dirty safety curtains	Clean safety curtains.
Transducer alignment mechanism stained with glue	Clean the transducer alignment mechanism.
Flamed safety relays.	Replace relays
Lack of pressure in rollers	Regulate air pressure of the rollers at 22 psi.

Table 6 Preventive actions
Source: Project contribution, unpublished

Phase 6: Grouping of preventive measures in their different categories. Preparation of the Maintenance Plan, list of improvements, training plans and operation and maintenance procedures. (Martín, 1998)

Mechanic	Electric
Recover oil level in lubricating vessel of FRL unit	Replace fuses
Clean and lubricate bearing guides.	Repair emergency brakes or replace them.
Clean the transducer alignment mechanism	Replace inductive sensor.
Replace linear bearing guides.	Clean safety curtains.
Changing guide bearings	Replace relays
Alignment of transmission pulleys	Solder the card or replace voltage sensor.

Table 7 Grouping of preventive actions
Source: Project contribution, unpublished

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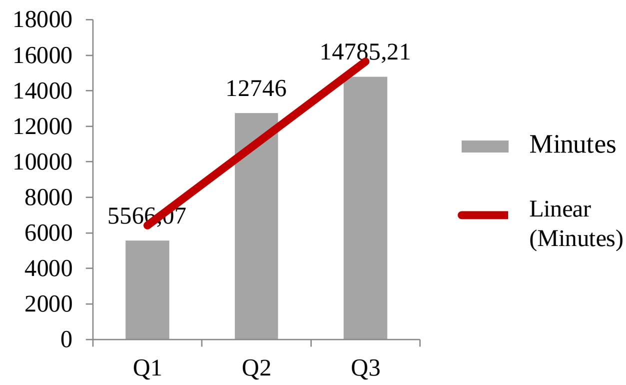
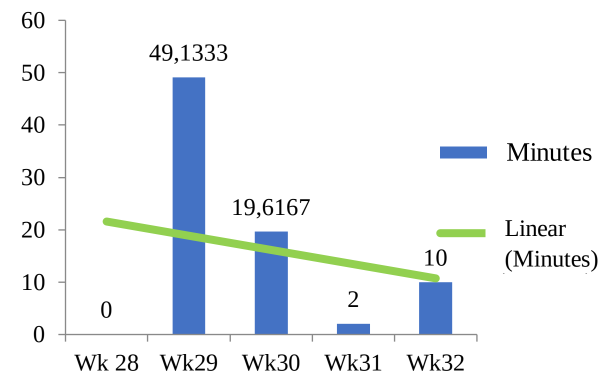
Results

The implementation of the RCM methodology was achieved. It was possible to improve the MTBF and MTTR indicators, contributing to the increased availability of the pleating machine and, as a consequence, the productivity.



Graph 1 MTBF Indicator
Source: Project contribution, unpublished



Graph 2 MTTR Indicator
Source: Project contribution, unpublished

Conclusions

The use of the RCM methodology is important, since it led to the development of a preventive maintenance plan that would contribute to the improvement of the MTBF and MTTR indicators to reduce machine downtime and thus achieve an increase in production.

References

Falcon, J. C. (2015). Gestion del mantenimiento centrado en la confiabilidad. Mexico.

García, G. S. (2015). Ingenierí del mantenimiento. Mexico: Renovetec.

Martin, A. K. (1998). Gestión de Mantenimiento Industrial. Madrid: Fundación Repsol.

O., D. S. (2010). Sistema de mantenimiento: Planeación y Control. Mexico: Limusa.

Villanueva, E. D. (2014). La Productividad en el mantenimiento industrial. Mexico: Grupo Editorial Patria.

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Change points in space-time, methodology and applications

Puntos de cambio en espacio- tiempo, metodología y aplicaciones

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Abstract

In this work, we review publications which analyze, develop and apply concepts of change points, in general, the formulation of the problem of the change point, and different problems, including some of its applications are presented. Applications include temporal, spatial and temporal-space change points, parametric and non-parametric methods are used.

Change points, Parametric, Non-Parametric

Resumen

En este trabajo se hace una revisión de publicaciones que analizan, desarrollan y aplican conceptos de puntos de cambio, en general se presenta la formulación del problema del punto de cambio, y diferentes problemas del mismo, incluidas algunas de sus aplicaciones. Las aplicaciones incluyen puntos de cambio temporal, espacial y espacio temporales, se utilizan métodos paramétricos y no paramétricos

Puntos de cambio, Paramétricos, No paramétricos

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Introduction

The change point is one of the central problems of statistical inference, as it relates to the theory of statistical control, hypothesis tests (when detecting whether there is any change in the succession of random variables observed) and estimation theory (when estimating the number of changes and their corresponding locations). Change point problems originally arose in quality control and can generally be found in various experimental and mathematical disciplines such as environmental sciences, epidemiology, seismic signal processes, economics, finance, geology, medicine, biology, physics, etc. (Chen & Gupta, 2012). The change points are presented abruptly and gradually (Brodsky & Darkhovsky, 1993), and (Brodsky, Brodsky, & Darkhovsky, 2000) carry out their analysis on independent and dependent random variables over time and space.

The general objective of this paper was to investigate and analyze the methodologies developed in the study of change points and their different applications in the space-time problem. The methodologies consist in finding the test statistics and by means of it, when contrasting the hypotheses, deciding whether there are change points.

Most spatial-temporal analysis approaches are developed in three separate stages (separate spatial analysis for each time point, separate temporal analysis for each location and analysis of spatial-temporal data with methods for random fields in R^{d+1} (Schabenberger & Gotway, 2004). The first two approaches can be considered conditional methods because they isolate a particular point or time location and apply standard techniques for the type of resulting data. A two-stage variation on the topic is to combine the results of the conditional analyses into a second stage. Two-stage approaches are common in statistical application, in which multiple sources of variation exist.

Analyses of space-time, spatial and temporal change points are performed under different approaches: nonparametric and parametric. In this work, different approaches are included regarding the change points, both spatial, temporal and space-time; parametric and non-parametric.

The detection of change points is important, because when estimating future events, we want accurate models and to be able to predict with greater precision. This is achieved using some methodology of change points; therefore, we analyze and include methodologies and some works that apply them, in addition to some works in which some other methodologies not presented in this article were used.

In general, the problem of change points in space and time treats different change points according to (Xun, Shashi, & Reem, 2014), the changes in space and time are classified in the following way: changes in statistical parameters, change in the value, change in the model adjusted to the data, this is reflected in the change of behavior of the trend which can be linear or polynomial, change in the attributes of the slope. In space, the changes are: raster-based, vector-based and image-based. In spacetime the change also refers to volume.

This paper is structured as follows: the second section presents the formulation of the problem of change points with respect to parameters, their classification and diagnostic methods; section 3 presents change point methods in parametric and nonparametric form; section 4 summarizes in tables some applications with different parametric and nonparametric methods; section 5 includes the results; section 6 presents the conclusions; and section 7 provides the bibliographic references. The detection of change points is important, because when estimating future events, we want accurate models and to be able to predict with greater precision. This is achieved using some methodology of change points; therefore, we analyze and include methodologies and some works that apply them, in addition to some works in which some other methodologies not presented in this article were used.

Change Point Formulation

When a change point is mentioned, the first question that comes to mind is: what is a change point? (Chen & Gupta, 2012). It is defined as the site, or point in time t, in a succession of data $\{x_{t_i}\}$ $i = 1,..,n$ observed and ordered with respect to time, such that these observations follow a distribution F_1, before a point, and in another point after it, the distribution is F_2.

From the statistical point of view, the succession of observations shows a non-homogeneous behaviour. In general, the problem of change points according to (Chen & Gupta, 2012) is visualised as follows:

Let $X_1, X_2, \ldots, X_n$ be a succession of independent random vectors (or variables) with probability distribution functions $F_1, F_2, \ldots, F_n$, respectively. Then the problem of change points is to test the null hypothesis H_0 of the non-existence of change against the alternative H_a that there is at least one change point:

$$H_0: F_1 = F_2 = \cdots = F_n \quad vs$$
$$H_a: F_1 = \cdots = F_{(k_1)} \neq F_{(k_{1+1})} = \cdots = F_{(k_q)} \neq F_{(k_{q+1})} = \cdots = F_n$$

Where $1 < k_1 < k_2 < \cdots < k_q < n$; q is the unknown number of change points and $k_1, k_2, \ldots, k_q$ are the respective unknown positions that have to be estimated. If the distributions $F_1, F_2, \ldots, F_n$ become a common parametric family $F(\theta)$, where $\theta \in R^p$, then the problem of change points is to test the null hypothesis H_0 on the non-existence of change in the parameters $\theta_i, i = 1, \ldots, n$ of the population against the alternative H_a that there is at least one change point:

$$H_0: \theta_1 = \theta_2 = \cdots = \theta_n = \theta, \quad unknown \quad vs$$
$$H_a: \theta_1 = \cdots = \theta_{(k_1)} \neq \theta_{(k_{1+1})} = \cdots = \theta_{(k_q)} \neq \theta_{(k_{q+1})} = \cdots = \theta_n$$

where q *and* $k_1, k_2, \ldots, k_q$ must be estimated. These hypotheses together reveal the inference aspects of change points to determine if any change point exists in the process, estimate their number and their respective positions.

In several cases it is assumed that the observations are independent and identically distributed (i.i.d.), since the analysis is more complex if there is dependence between the observations. In the case of time series, the dependence occurs among the observations within each time segment; in the case of space-time data, the dependence occurs over space and time.

According to (Brodsky & Darkhovsky, 1993) and (Brodsky, Brodsky, & Darkhovsky, 2000) the problems and methods of diagnosing change points can be classified as follows:

By the character of the information on the diagnostic object: Retrospective analysis (a posteriori) and sequential analysis; by the character of statistical diagnostic methods: Parametric, nonparametric and semiparametric methods; by the character of the diagnostic object: Statistical diagnostic problems for random processes (in discrete or continuous time) and statistical diagnostic problems for random fields; by the character of statistical dependence between observations: change point problems can be formulated for random sequences with independent observations, and change point problems for dependent observations in time or space, in a one-dimensional and multidimensional form, a single change point or multiple change points; by the mechanism of change in the state of the diagnostic object: Detection of abrupt change (change point problems), detection of gradual change, detection in regression relations; by the mechanism of change in the state of the diagnostic object: Detection of abrupt change (change point problems), detection of gradual change, detection in regression relations. These changes are observed in the probabilistic characteristics of the observations.

Change Point Methods

This section presents parametric and non-parametric methods of change points. Then, they will be described in detail.

Parametric methods

The parametric methods are: the standard normal homogeneity test, Von Newman, Buishand Ranges, t Motion, the Cumulative Anomaly Test and one more based on kernel. The standard normal homogeneity test was developed by (Alexandersson, 1986) to compare the mean of the first *k* years of recording with that of the last *n* - *k* years, the hypothesis contrast is:

$$H_0: \mu_1 = \mu_2 \quad vs \quad H_a: \mu_1 \neq \mu_2$$

where μ_1 is the average of the first *k* years and μ_2 is the average of the last *n* - *k* years. The $T(k)$ statistic is calculated as equation (1) based on equations (2) and (3):

$$T(k) = k\,\bar{z_1}^2 + (n-k)\bar{z_2}^2, \quad k = 1, \ldots, n, \quad (1)$$

where

$$\bar{z_1} = \frac{1}{k}\sum_{i=1}^{k} z_i \quad \text{, and} \quad (2)$$

Y $\bar{z_2} = \frac{1}{n-k}\sum_{i=k+1}^{n} z_i.$ (3)

If a change occurs in year k, then $T(k)$ peaks near year $k = k_0$. Test statistics T_0 is given in equation (4)

$$T_0 = \max(T(k))\ for \quad 1 \le k \le n\,. \qquad (4)$$

The null hypothesis is rejected when T_0 is larger than a certain critical value, i.e. there is a change point. Another proof is the relation of (Von Newman, 1941), which is related to the first-order serial correlation coeficiente. The relation, N, of Von Neumann is defined as the ratio of the difference of the successive mean square (year to year) and the sample mean square (Von Newman, 1941). The test statistic for change point detection in the time series $x_1, x_2, \dots, x_n$, is described in equation (5):

$$N = \frac{\sum_{i=1}^{n}(x_i - x_{i-1})^2}{\sum_{i=1}^{n}(x_i - \bar{x})^2} \qquad (5)$$

The X_i are normally distributed with mean μ and variance σ^2. The hypotheses regarding the change point with respect to the mean are the following:

$H_0: E(N), i = 1, \dots, m,$ (i.e., the average is constant)

Vs

$H_a: E(N) + \Delta, i = m+1, \dots, n$ (there is a change of size Δ).

For homogeneous series, the expected value under the null hypothesis is constant $E(N) = 2$. Non-homogeneous series or samples with a change will have a value of N less than 2; any other value implies that the time series has a rapid variation in its mean.

One more parametric test is the Buishand range test. (Buishand, 1982) developed this statistical test. The adjusted partial sum, which is the cumulative deviation of the mean for the observation k of a series $x_1, x_2, \dots, x_n$ with mean μ, can be calculated using the equations (6) and (7):

$$S_{0^*} = 0, \quad \text{and} \qquad (6)$$

$$S_{k^*} = \sum_{i=1}^{k}(x_i - \bar{x})\,,\ k = 1, \dots, n \qquad (7)$$

Where X_i have normal distribution. For homogeneous series, the values of S_{k^*} fluctuate around zero, since in the random time series the deviation from its mean is generally distributed on both sides of the mean of the series. If the series breaks in year K, then S_{k^*} reaches a maximum (negative change) or a minimum (positive displacement) near year k = K.

The readjusted partial sums are obtained by dividing the S_{k^*} by the sample standard deviation, as shown in the equation (8):

$$S_{k^{**}} = \frac{S_{k^*}}{D_y}, \qquad k = 0, \dots, n, \qquad (8)$$

With (10)

$$D_y^2 = \sum_{i=1}^{n}\frac{(y_i - \bar{y})^2}{n} \qquad (10)$$

The homogeneity test is based on the adjusted rescalated partial sums $S_{k^{**}}$. The statistic for homogeneity developments is (11):

$$Q = \max_{0 \le k \le n} |\,S_{k^{**}}|\,, \qquad (11)$$

high Q values are an indication of a change.

Another test is the t Motion test, which is used by (Yin, Liu, Yi, & Liu , 2015), who used it to detect possible abrupt change points. The t Motion test is the t-test of two samples (Snedecor & Cochran, 1989) which is used to determine if two population means are equal. The data can be paired or unpaired. If they are paired it means that there is a one-to-one correspondence between the values in the two samples, for paired samples the difference is usually calculated. For unpaired samples, the sample sizes for two samples may not be the same. Sample variances can be assumed to be the same or different.

The hypothesis contrast to the mean to detect a change is:

$$H_0: \mu = \mu_2 \quad vs \quad H_a: \mu_1 \ne \mu_2,$$

When the variances are the same, the test statistic is (12):

$$t = \frac{\bar{x}_1 - \bar{x}_2}{s\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}} \qquad (12)$$

Where, $s = \sqrt{\frac{n_1 s_1^2 + n_1 s_2^2}{n_1 + n_2 - 2}}$.

This test statistic is used to detect a change point, for a given time series x_n which has n random samples, the reference point is set for a given time. The samples of two subsucessions before and after a point data are n_1 and n_2. $\bar{x}_1$ and $\bar{x}_2$ are the average of two subsucessions and s_1^2 and $s_2^2$are the variances of two subsucessions.

The t Motion test according to (Yin, Liu, Yi, & Liu , 2015) is carried out in three steps to detect abrupt change. First, the same length of two subsections before or after the point data is defined; normally, $n_1 = n_2$. Second, according to the mathematical expression in (2), the statistical value of two subsections is successively calculated using the t Motion method for a set of point data. Third, the average values of two samples are compared at a given significance level to detect the change. If $|t_1| < t_\alpha$, the analyzed variable has abrupt change in the point data.

A test analyzed by (Lishan, Suiji, & Xiaoli, 2010) is the cumulative anomaly method for revealing abrupt changes in water discharge and suspended sediment concentration (SSC). According to (Lishan, Suiji, & Xiaoli, 2010), mathematically cumulative anomaly is a method for distinguishing a trend change from discrete data and is widely used in meteorology to analyze variations in precipitation and temperature. For a discrete x_i series, the cumulative anomaly (X_t) for point data x_t can be expressed as (13):

$$\hat{X}_t = \sum_{i=1}^{t} (X_i - \bar{X}), \ \ t = 1,2,\dots,n \qquad (13)$$

$with\, \bar{X} = \frac{1}{n}\sum_{i=1}^{n} x_i$, and $\bar{X}$ is the mean value of the x_i series, and n is the number of discrete points. As the equation suggests, the cumulative anomaly can be used to analyze the magnitude of the fluctuation of a series of discrete data, usually the increase in the cumulative anomaly value indicates the point data involved that are larger than the average, otherwise lower than the average. In the study, the variable x represents the average annual discharge and the average annual suspended sediment concentration (SSC), respectively.

This is a test that has been used by some other researchers besides Ran et al. to analyze changes: (Suiji, Xunxia, Ming, & Zhao, 2012) and for changes in space-time (Xiujing, Shifeng, Yongyong, & Cuicui, 2013).

Another method is Single Spectrum Analysis (SSA) ((Morkvina, 2001) and (Morskvina & Zhiglijavsky, 2003)), this is a powerful technique of time series analysis, used to detect change points.

Algorithm to detect change points:

Let $x_1, x_2, \dots, x_T$, a time series with T<∞. Select: from the window width N(N≤T) the lag parameter ($M \leq \frac{N}{2}$, k = N – M + 1 and 0≤p<q, I=(1,..,l) where l denotes the number of eigenvectors that form the base of the subspace.

1. The base matrix $X^{(n)}$, called the trajectory matrix, $X^{(n)}$ has multivariate data with M characteristics and k observations. Columns $X_j^{(n)}$ with j=1,...,n of $X^{(n)}$ are considered as vectors falling into dimensional M space.

2. The covariance lag matrix.. $R_n = X^{(n)}(X^{(n)})^T$.

3. The M eigenvalues and eigenvectors of R_n.

4. $D_{n,I,p,q}$ is the matrix of the sum of the differences for the vectors $X_j^{(n)}$, the matrix with columns $X_j^{(n)}$ $(j = p + 1, \dots, q)$ is called the test matrix in (14),

$$D_{n,I,p,q} = \sum_{j=p+1}^{q} ((X_j^{(n)})^T X_j^{(n)} - (X_j^{(n)})^T U U^{T X_j^{(n)}}. \qquad (14)$$

And $U_{i1}, \dots, U_{iI}$ denotes the eigenvectors that form the basis of subspace $L_{n,I}, l < M$.

5. Calculate the normalized square distance S_n, like in 15

$$S_n = \frac{\tilde{D}_{n,I,p,q}}{v_n} \qquad (15)$$

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and $\widetilde{D}_{n,I,p,q} = \frac{1}{M(q-p)} D_{n,I,p,q}$ which is the normalized sum of square distances (normalization is made with respect to the number of elements in the test matrix). v_j is an estimator of the normalized sum of square distances $\widetilde{D}_{n,I,p,q}$ in the time intervals [j + 1, j + N] where the no change hypothesis can be accepted. It is suggested to use $\widetilde{D}_{\tilde{n},I,p,q}$, where $\tilde{n}$ is the largest value of j<n such that the null hypothesis of no change in the interval [j + 1, j + N] has been accepted.

The decision rule in the proposed algorithm is to declare a change if for any n, $S_n \geq H$, where H is a fixed threshold, i.e. large values of $D_{n,I,p,q}$ and S_n indicate that there is a change in the structure of the series.

Note: A general recommendation is to select p ≥ k; this makes the base columns and the test matrix consist of different elements. In this case, the algorithm is more sensitive to changes than its economic version (in the sense of the number of x_t involved in each iteration n) when p < k and so, some of the base columns and test matrices match.

To obtain a smoother behaviour of the test statistic $D_{n,I,p,q}$, q needs to be selected slightly larger than p. If the difference q-p is also large, then the behaviour of $D_{n,I,p,q}$ becomes larger; this perhaps for example when p = 0 and q = p (that is, the base and the test matrix coincide).

Regarding the kernel-based space-time change points test is the work of (Jansenberger & Steinnocher , 2014) who made a contribution which focuses on space-time changes. For the spatial quantification of such changes, the dual kernel density estimation method was used. For such method, two different data sets were related to each other. Changes in spatial concentration of grocery stores of two retail groups in the province of Austria were analyzed for 1998 and 2001.

The researchers use a quartic kernel function. However, since the result of an analysis is not strongly influenced by the selected function, there are no rules concerning the selection of an appropriate function. There are several different kernel functions, the most common kernel function is the normal distribution function in (16):

$$k\left(\frac{d_i}{n}\right) = \frac{1}{2\pi} \exp\left[-\frac{1}{2}\left(\frac{d_i}{\mu}\right)^2\right] \quad (16)$$

With $\mu = \left(\frac{s-s_i}{b}\right)$, based on this function the density estimate is expressed in (17):

$$\hat{f}(s) = \frac{1}{b^2} \sum_{i=1}^{n} k\left(\frac{d_i}{b}\right) \quad (17)$$

where d_i is the distance between the s points and the location of the observed point. Because bandwidth b is the standard deviation of the normal distribution, this function extends to infinity in all directions, i.e. it was applied to each of the points in the region.

In this analysis, the quartic Kernel function is used, which has a circumscribed radius, which is also the bandwidth. The quartic kernel function is applied to a limited area around each location and has the functional form in (18)

$$K(\mu) = \begin{cases} \frac{3}{4}(1-\mu^2\mu)^2 & for\ \mu^2\mu \leq 1 \\ 0 & d.o.f. \end{cases} \quad (18)$$

Kernel density is also estimated, which is an interpolation technique that relates individual point locations or points for an entire area and provides estimates of density λ(s) (19), at a location within the study region R.

$$\lambda(\hat{s}) = \sum_{i=1}^{n} k\left(\frac{d_i}{b}\right) \quad (19)$$

If the dual kernel is applied to a variable, this is known as a singular density estimate. If it is applied to two variables, this is called a dual density estimate. In the latter case, a kernel density is estimated for each of the variables individually and then the two density estimates are related to each other by a simple algebraic operation such as a sum, difference and quotient. The most commonly used operation is the quotient. In this study, however, the difference in absolute value of the densities was used and with it the space-time changes in the region of study were visualized.

Non-parametric tests

Within the non-parametric tests, there are: Pettit, Mann Kendall and Lepage. The nonparametric Pettitt test (Pettitt, 1979) detects a change in an unknown time, he uses a version of the test of two Mann-Whitney samples, and calculates their statistical significance.

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He considers a time series $x_i (1 \leq i \leq n)$) and uses a $U_{t,n}$ statistic, which is equivalent to a Mann-Withney statistic, which is used to prove that the two samples $x_1, \ldots, x_t$ and $x_{t+1}, \ldots, x_n$, are from the same population. The null hypothesis H_0 of the Pettitt test is the absence of change points, while the alternative hypothesis is the existence of a change point. It is considered to (20)

$$D_{ij} = sgn(X_i - X_j) \quad (20)$$

where $sgn(x) = \begin{cases} 1, & x > 0 \\ 0\ , & x = 0 \\ -1 & x < 0. \end{cases}$

The statistic test is given in (21):

$$U_{t,n} = \sum_{i=1}^{t} \sum_{j=1+1}^{n} D_{ij}, \quad t = 2, \ldots, n. \quad (21)$$

The Pettitt test uses the test statistics given in (22),

$$k_t = \max_{1 \leq t \leq n} |U_{t,n}| \quad (22)$$

For testing one tail and for changing directions, the statistics given in (23) are used,

$$k_1^+ = \max_{1 \leq t \leq n} |U_{t,n}|, \quad k_1^- = \min_{1 \leq t \leq n} |U_{t,n}|. \quad (23)$$

Obviously $k_t = \max(k_t^+, k_t^-)$. It should be noted that in the null hypothesis $H_0, E(D_{ij}) = 0$ and the distribution of $U_{t,n}$ is symmetrical around zero for each t. So, k_t^+ and k_t^- have the same null distribution. The statistics k_t^+ are k_t^- are from a tail, and use the theory of Mann-Whitney, k_t^+ can be expected to be large if there has been a downward change in the level of the beginning of the series. k_t^+ can be large if $F_1(x) \leq F_2(x)$, with strict inequality for at least some x. Similarly, k_t^- can be expected to be large if there has been an upward change or $F_1(x) \geq F_2(x)$.

The significant change point is at the maximum $U_{t,n}$ value and the level of significance associated with k_t^+ and k_t^- is determined approximately by (24)

$$\rho = 2 \exp\left(-\frac{6k_t^2}{n^3 + n^2}\right), \quad (24)$$

if ρ is smaller than the specific significance level, e.g. 0.05, the null hypothesis is rejected. In other words, if there is a significant change point, the time series is divided into 2 parts at the location of the change point t.

The probability of approximate significance for a change point is defined as p = 1 - ρ. The Mann-Kendall test is a non-parametric method for trend detection and change points due to its robustness and simplicity. The Mann-Kendall test has been widely used to evaluate the monotonic trend significance of hydrometeorological variables. (Liu, Xu, & Huang, 2012) cites this test in their analysis and mention the Mann-kendall- Sneyers test; while (Sneyers, 1990) calls this statistic the Mann statistic. For time series, the magnitudes $x_i (i = 1,2, \ldots, n)$ mean time series that are compared with $x_j (i = 1,2, \ldots, i-1)$. For each comparison, the number of cases is counted $x_j > x_i$ which is denoted by r_i. The null hypothesis H_0 indicates the existence of no trend in the time series, while the alternative hypothesis H_1 establishes that there is a trend in the data set. Under the null hypothesis (no trend), the range series is (25):

$$S_k = \sum_{i=1}^{k} r_i, \quad (25)$$

Where

$$r_i = \begin{cases} +1 & x_i > x_j \\ & j = 1,2,3, \ldots, i \\ 0 & x_i \leq x_j \end{cases}$$

has normal distribution with mean and variance given by: $E(S_k) = \frac{k(k+1)}{4}$, $var(S_k) = \frac{k(k-1)(2k+5)}{72}$.

Forward Sequential Statistics in (26)

$$U_{F_k} = \frac{[S_k - E(S_k)]}{\sqrt{var(S_k)}} \quad k = 1,2, \ldots, n \quad (26)$$

is a standardized normal variable. The backward sequence U_{B_k} is estimated using the same equation but with an inverted series of data. In a 2 tail trend test, the null hypothesis is accepted with a level of significance α if $|U_{F_k}| \leq (U_{F_k})_{1-\frac{\alpha}{2}}$ where $(U_{F_k})_{1-\frac{\alpha}{2}}$ is the critical value of the standard normal distribution with a probability α. U_{F_k}>0 denotes an upward trend, while the opposite denotes a downward trend (i.e U_{B_k} is similar to U_{F_k}).

The sequential version of the test used allows the detection of the approximate time of occurrence of the change of trend by localizing the intersection of the forward and backward curves of the test statistic.

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A point of intersection within the range of confidence indicates a change point. Another nonparametric test is the Lepage test. This is a two-sample test for location and dispersion (Lepage, 1971), which has been widely used to detect changes such as long-term trends, cyclical variations and staggered changes for precipitation. Lepage assumes that the size of the study series is equal to or greater than ten and the Lepage statistic (HK) follows the Chi-square distribution ($\chi 2$) with two degrees of freedom. It is assumed that the samples come from continuous distributions and are independent. The Lepage (HK) statistic is given in (27):

$$HK = \frac{[W-E(W)]^2}{V(W)} + \frac{[A-E(A)]^2}{V(A)} \quad (27)$$

Let $x = (x_1, x_2, \dots, x_{n1})$ and $y = (y_1, y_2, \dots, y_{n2})$ two independent samples of size n_1 and n_2. It is assumed that $\mu_i = 1$ if the smallest i-th observation in a combined sample size (n_1, n_2) belongs to x and $\mu_i = 0$ if it belongs to y.

The null hypothesis H_0 of the Lepage test assumes that the distributions from which the two samples come are equal, contrasting against the alternative H_a in which they are considered to be different. If the HK test statistic exceeds 5.99, the difference between two samples is judged as significant at the confidence level of 95 percent (significance level of 5 percent), i.e. the null hypothesis that the distributions are equal is rejected, therefore there is a change point.

The terms in Eq. (27) can be derived from equations (28), (29), (30) and (31).

$$W = \sum_{i=1}^{n_1+n_2} i\mu_i, \quad (28)$$

$$E(W) = \frac{n_1(n_1+n_2+1)}{2} \quad (29)$$

$$V(W) = \frac{n_1 n_2(n_1+n_2+1)}{2} \quad (30)$$

$$A = \frac{1}{2}n_1\big((n_1+n_2+1)+1\big) + \sum_{i=1}^{n_1+n_2} |i - \tfrac{1}{2}(n_1+n_2+1)|\mu_i \quad (31)$$

If $(n_1 + n_2)$ is even $E(A)$ and $V(A)$ will be calculated as in (32) and (33):

$$E[A] = \frac{n_1(n_1+n_2+2)}{4}, \text{ and} \quad (32)$$

$$V(A) = \frac{n_1 n_2(n_1+n_2-2)(n_1+n_2+2)}{48(n_1+n_2-2)}. \quad (33)$$

The statistical characteristics of the segments divided by the change points are detected by the mean and the coefficient of variation (Cv). Thus, $\mu_x = E[x] = \mu_1'$ and $Cv = \frac{S_x}{x}$, where $S_x = \sqrt{\frac{\sum_{i=1}^{k}(x_i-\bar{x})^2}{(n-1)}}$.

Application problems

Three tables are presented below, which summarize the different application problems of the change points studied and the methodology used for their detection, as well as the researchers who have used the methodologies. The three tables consist of three columns, which contain the problem or application, the author or authors and the model or methodology used to detect the change point or points. In the first table there are applications in which the change point analysis is carried out by means of the methods listed in column 3, superscript is placed, the models range from 1 to 4. In the second table, superscript is placed for researchers who use the model listed in column 3, the models range from 1 to 15. In table 3 the same procedure is performed, models from 1 to 9 are listed and the researchers who used it are placed as superscripts.

Problem	Authors	Models
Lake temperature	(Chavaillaz, Joussaume, Bony, & Braconnot, 2015)[1]	1. Regression
Precipitation and temperature	(Skliris, y otros, 2014)[1]	
Contaminant concentration	(Abdel, El, Sean, Rong, & Yalin, 2011)[1]	
Precipitation and temperature	(Chengjing, y otros, 2012)[1]	
Change in ocean aerosols	(Cermak, Wild, Knutti, Mishchencko, & Heidinger, 2010)[1]	
Growth of Chinese spruce	(Ma, Shi, Wang, & He, 2006)[1]	
Land use change	(Bollinger, Kienast, Soliva, & Rhuterford, 2007)[1]	
Sea surface temperature	(González Taboada & Andón , 2012)[1]	
Vegetation index	(Luan, y otros, 2018)[1]	
Spatial concentration of grocery stores	(Jansenberger & Steinnocher , 2014)[2]	2.Kernel
Hydrology (flow)	(Yang, Chen, Xu, & Zhang, 2009) [3]	3. Single spectrum analysis
Climate (Precipitation)	(Xiujing, Shifeng, Yongyong, & Cuicui, 2013) [4]	4.Pettit

Table 1 Regression, Kernel, Single Spectrum Analysis, Pettit, t Motion, Buishand Ranges, Normal Standard Homogeneity and Von Newman

Problem	Authors	Models
Climate (temperature)	(Yin, Liu, Yi, & Liu , 2015)[1]	1.t Motion 2.Pettit
Climate (temperature)	(Malekian & Kazemzadeh, 2015)[1,2,3]	3. Ranges of buishand
Change in air temperature	(Chakraborty, y otros, 2017)[1,2,4,5]	4. Homogeneity Normal standard
Zink contamination	(Tlili, y otros, 2011)[6]	5.Von Neuman
Growth of Chinese spruce	(Ma, Shi, Wang, & He, 2006)[7]	6. Multivariate Statistics
Exotic Vegetation	(Tierney & Cushman, 2005)[8,10]	7. Gini and Lorentz Coefficient
Change of land use	(Bollinger, Kienast, Soliva, & Rhuterford, 2007)[9]	8.MANOVA 9. Logistic Regression
Soil breathing	(Akburak & Makineci, 2012)[10]	10.ANOVA
Detection of telecommunication fraud	(Hilas, Rekanos , & Mastorocostas, 2013)[11]	11.ARIMA 12.MEDIAN
Climate (Temperature)	(Luo, Bryan, Bellotti, & Williams , 2005)[12]	13.ANCOVA
Soil water content	(Cubera & Moreno, 2007)[13]	14.t Motion
Precipitation rates	(Chavaillaz, Joussaume, Bony, & Braconnot, 2015)[14,15]	15.Mann Kendall
Water temperature	(Peter, 2017)[2]	

Table 2 MANOVA, ARIMA, Bayesian space, Mann Kendall, Median and ANOVA

Problem	Authors	Models
Climate (precipitation)	(Chen, Kimb, & Kimc, 2016)[1]	1. Bayesian Space
Climate (temperature)	(Yin, Liu, Yi, & Liu , 2015)[2]	2.Mann Kendall
Climate (precipitation)	(Biana, y otros, 2017)[2,3]	3.Pettit
Change in air temperature	(Chakraborty, y otros, 2017)[3]	
Temperature in the lake	(Yankova, Villiger, Pernthaler, Schanz, & Posch , 2017)[2]	
Precipitation	(Adeyeri, Lamptey, Lawin, & Sanda, 2017)[3]	
Climate (temperature)	(Malekian & Kazemzadeh, 2015)[2,3]	
Climate (precipitation, flow)	(Gebremicael, Mohamed, Zaag, & Hagos, 2017)[2,3]	
Vegetation index, habitat change in estuary	(Marcoe & Pilson, 2017)[4]	4. Data comparison
Change of the beach	(Michalowska, Glowienka, & Pekala, 2016)[5]	5.Images 6.Bayesian space
Intellectual coefficient	(Cai, Lawson, McDermott, & Aelion, 2016)[6]	7. Yamamoto Method 8. Wavelet Method
Climate (Precipitation, temperature)	(Huiying, y otros, 2016)[7,8,9]	9.Trend rate

Table 3 Mann Kendall, Pettit, Lepage, Bayesian, spline, comparative data and images

Results

As a result of this research, the different applications, their authors and applied models are presented summarized in tables. It can be observed that the studies of hydrometeorological variables are of main interest.

As can be observed in the introduced methodologies, both parametric and nonparametric, what was done was to determine the test statistic and, by means of this, to contrast the hypotheses in order to decide whether there are change points. Therefore, the objective is to determine the test statistic in any proposed methodology, often having the need to obtain limit distributions in order to make the contrast.

In terms of applications, for example in Bayesian models, in order to find the aposteriori, both informative and non-informative aprioris can be worked on.

Conclusion

Many of the works on both parametric and non-parametric change points apply the methodology of change points in precipitation, temperature, change in air temperature, water temperature and water flow, to name a few. Although these application problems occur frequently, there are also some others that have been summarized in the tables of the application section, however the hydrometeorological variables as can be observed are of main interest. In the same way, it is of interest to identify the change points in the inference to obtain better accuracy.

References

Abdel, H., El, S., Sean, B., Rong, Z., & Yalin, C. (2011). Modelling temporal and spatial changes of PCBs in fish tissue from Lake Huron. *Environ Monit Assess, 173*, 611-623.

Adeyeri, Lamptey, Lawin, & Sanda. (2017). Spatio-Temporal Precipitation trend and homogeneity analysis in komadugu yobe Basin, Lake Chad region graduate research programme on climate change and water resources. *Climatol Weather Forecasting, 5*(3).

Akburak, S., & Makineci, E. (2012). Temporal changes of soil respiration under different tree species. *Environ. Monit Assess, 185*, 3349-3358.

ISSN 2410-3438

Alexandersson, H. (1986). A homogeneity test applied to precipitation. *Journal of Climatology, 6*, 661-675.

Biana, G., Dua, J., Songa, M., Xua, Y., Xiea, S., Zhenga, W., & Xuc, C. (2017). A procedure for quantifying runoff response to spatial and temporal changes of impervious surface in Qinhuai River basin of southeastern China. *Catena, 157*, 268-278.

Bollinger, J., Kienast, F., Soliva, R., & Rhuterford, G. (2007). Spatial sensitivity of species habitat patterns to scenarios of land use change (Switxerland). *Landscape Ecol., 22*, 773-789.

Brodsky, B. E., & Darkhovsky, B. S. (1993). *Mathematics and its Applications Noparametrics Methods in Change-Point Problems* (Vol. 243). Kluer Academic Publishers.

Brodsky, Brodsky, B. E., & Darkhovsky, B. S. (2000). *Non Parametric Diagnostic Problems and Methods. Mathematics and Its Aplications.* Kluwer Academic, Dordrecht.

Buishand, T. A. (1982). Some methods for testing the homogeneity of rainfall records. *Journal of Hidrology, 58*, 11-27.

Cai, B., Lawson, A., McDermott, S., & Aelion, C. (2016). A Bayesian semiparametric approach with change points for spatial ordinal data. *Stat. Methods Med. Res., 25*(2), 644-658.

Cermak, J., Wild, M., Knutti, R., Mishchencko, M., & Heidinger, K. (2010). Consistency of global derived aerosol and cloud data sets with recent brightening observations. *Geophysical research Letters, 37*.

Chakraborty, D., Saha, S., Sink, R., Sethy , B., Kumar , A., Saikia, U., . . . Daschaudhuri, D. (2017). Trend Analysis and Change Point Detection of North Eastern India. *Environ. Process*.

Chavaillaz, Y., Joussaume, S., Bony, S., & Braconnot, P. (2015). Spatial stabilization and intensification of moistering and drying rate patterns under future climate change. *Clim Dyn, 47*, 951-965.

Chen, J., & Gupta, A. (2012). *Parametric Statistical Changepoint Analysis.* Bogota: Birkhauser.

Chen, S., Kimb, S., & Kimc, T.-W. (2016). Spatial change Assessment of the observed and proyected extreme precipitation via change point detection. *Procedia Engineering, 154*, 1359-1367.

Chengjing, N., Hairong, L., Linsheng, Y., Ye, C., Erfu, D., Shaohong, W., . . . Yongfeng, L. (2012). Spatial and temporal changes in extreme temperature and extreme precipitation in Guangxi. *Quaternary International, 263*, 162-171.

Cubera, E., & Moreno, G. (2007). Effect of single Quercus ilex trees upon spatial and seasonal changes in soil water content in deshesas of central western Spain. *Ann. For. Sci., 64*, 355-364.

Gebremicael, T., Mohamed, Y., Zaag, P., & Hagos, E. (2017). Temporal and spatial changes of rainfall and streamflow in the Upper Tekeze-Atbara river basin Ethiopia. *Hydrol. Earth Syst Sci., 21*, 2127-2142.

González Taboada, F., & Andón , R. (2012). Patterns of change in sea superface temperature in the North Atlantic during the last three decades: beyond mean trends. *Climatic Changes, 115*, 419-431.

Hilas, C., Rekanos , L., & Mastorocostas, P. (2013). *Change Point Detection in Time Series Using Higher-Order Statistics: A Heuristic Approach.* Mathematical Problems in Engineering.

Huiying, Z., Lijuan , G., Huihui, Q., Haixia, Z., Xiufen, L., & Heilongjiang, Z. (2016). The climate change variations in the northern Greater Kningan Mountains during the past centuries, Institute of Meteorological Science, Harbin 150030, China. *J. Geogr. Sci., 26*(5), 585-602.

Jansenberger, E., & Steinnocher , S. (2014). Dual Kernel Density Estimation as a Method Describing Spatio Temporal Changes in the Upper Austrian Food Retailling Market. *7th AGILE Conference on Geographic Information Science 29 April- 1 Mayo 2004.*

ISSN 2410-3438

Lepage, Y. (1971). A Combination of Wilcoxon´s anAnsari Bradley´s Statistics. *Biometrika, 58*(1), 213-217.

Lishan, R., Suiji, W., & Xiaoli, F. (2010). Channel change at Toudaoguai Station and its responses to the operation of upstream reservoirs in the upper Yellow River. *J. Geogr. Sci.*, 231-247.

Liu, L., Xu, Z., & Huang, J.-X. (2012). Spatio temporal variation and abrupt changes for majer climate variables in the Taihu Basin, China. *Stch Environ Res Risk Assess, 26*, 777-791.

Luan, J., Liu, D., Zhang, L., Huang, Q., Feng, J., Lin, M., & Li, g. (2018). Analysis of the spatial-temporal change of the vegetation index in the upper reach of Han River Basin in 2000-2016. *Proc. IAHS, 379*, 287-292.

Luo, Q., Bryan, B., Bellotti, W., & Williams , M. (2005). Spatial analysis of enviromental change impacts on wheat production in mid-lower north, sourt australian. *Climatic Change, 72*, 213-228.

Ma, Z., Shi, J., Wang, G., & He, Z. (2006). Temporal changes in the inequality of growth of Cunninghamia lanceolata (Lamb) Hook: a novel application of the Gini coefficient and Lorenz asymmetry. *Genetica, 126*, 343-351.

Malekian, A., & Kazemzadeh, M. (2015). Spatio-Temporal Analysis of Regional Trends and Shift Changes of Autocorrelated Temperature Series in Urmia Lake Basin. *Water Recour Manage, 30*, 785-803.

Marcoe, K., & Pilson, S. (2017). Habitat change in the lower Columbia River estuary 1870-2009. *J. Coast Conserv, 21*, 505-525.

Michalowska, K., Glowienka, E., & Pekala, A. (2016). Spatial-temporal detection of changes southern coast of the baltic sea based on multitemporal aerial photographs. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciencies*, XLI-B2.

Morkvina, V. (2001). Aplication of the singular spectrum analysis for change-point detection in time series. *Ph. D. Thesi, Cardi University*.

Morskvina, V., & Zhiglijavsky, A. (2003). An on singular based on singular spectrum analysis for change-point detection, comunication in statistics. *Stat. Simul., 32*, 319-352.

Peter, A. (2017). Long-term temporal and spatial changes in the richness and relative abundance of the inshore fish community of the British North Sea Coast. *Journal of Sea Reseach*.

Pettitt, A. (1979). A Non-Parametric Approach to the Change-Point Problem. *Jornal of the Royal Statistical Society, Series C (Applied Statistics), 28*(2), 126-135.

Quant, R. E. (1958). The estimation of parameters of a linear regression system obeying two separate regimes. *J. Amer. Statist. Assoc., 50*, 853-880.

Schabenberger, & Gotway. (2004). *Statistical methods for spatial data analysis.* CRC Press.

Skliris, N., Marsh, R., Josey, S. A., Good, S. A., Liu, C., & Allan, R. P. (2014). Salinity changes in the World Ocean since 1950 in relation to changing suface freshwater fluxes. *Clim Dyn, 43*, 709-736.

Tierney, T., & Cushman, J. (2005). Temporal changes Temporal changes in native exotic vegetation and soild characteristics following disturbances by feral pigs in a California grassland. *Biological Invasions, 8*, 1073-1089.

Tlili, A., Corcoll, N., Bonet, B., Moirin, S., Montuelle, B., Bérad, A., & Guasch, H. (2011). In situ spatio-temporal changes in pollution-induced community tolerance to zinc in autotrophic and heterotrophic biofilm communities. *Ecotoxicology, 20*, 1823-1839.

Von Newman, J. (1941). Distribution of the Ratio of the Mean Square Successive Difference to the variance. *The Annals of Mathematical Statistics, 12*(4), 367-395.

Xiujing, M., Shifeng, Z., Yongyong, Z., & Cuicui, W. (2013). Temporal and spatial changes of temperature and precipitation in Hexi Corridor during 1955-2011. *J. Geogr. Sci., 23*(4), 653-667.

Xun, Z., Shashi, S., & Reem, Y. (2014). Spatial temporal change footprint pattern discovery: an inter-disciplinary survey. *WIREs Data Mining Knowl Discov, 4*, 1-23.

ISSN 2410-3438

Yang, T., Chen, X., Xu, C., & Zhang, Z.-C. (2009). Estimation as a Method Describing Spatio Temporal Changes in the Upper Austrian Food Retailling Market. *Stochastic Environmental Research and Risk Assessment, 23*, 1071-1087.

Yankova, Y., Villiger, J., Pernthaler, J., Schanz, F., & Posch , T. (2017). Prolongation, deepening and warming of the metalimnion change habitat conditions of the harmful filamentous cyanobacterium Planktothrix rubencens in a prealpine lake. *Hydrobiologia, 776*, 125-138.

Yin, Y., Liu, H., Yi, X., & Liu , W. (2015). Spatiotem,poral Variation and Abrupt Analysis of Temperature fron 1960 to in the Huang-Huai-Hai Plain, China2012. *Advances in Meteorology*.

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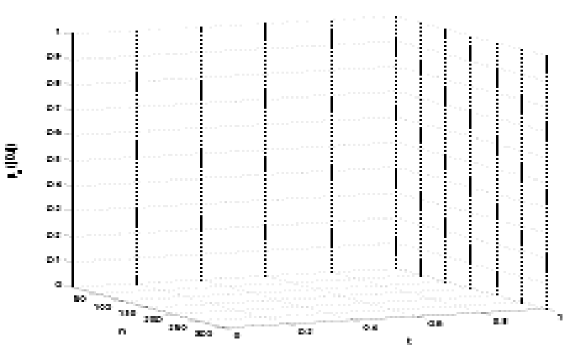

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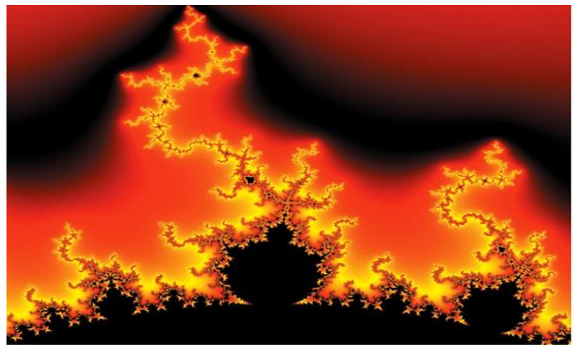

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