TEST OF PAGE-HINCKLEY, AN APPROACH FOR FAULT DETECTION IN AN AGRO-ALIMENTARY PRODUCTION SYSTEM

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ABSTRACT
The increasingly important automation of the manufacturing processes has made into evidence the needs in dependability for the installations. To ensure the industrial process dependability, the establishment of a monitoring system is primordial whose role is to recognize and to indicate in real time the behavior anomalies starting from information available on the system. Indeed the function of monitoring of a system is to detect, locate and diagnose the faults, which can affect its performances and its dependability.
The objective of these communication consists of the study and the conception of a detection module based on the techniques of static analysis and modelling, the matter is of establishing the operations which starting from the data coming from the industrial system make it possible to detect the abnormal situations in order to prevent or to reduce the dysfunction risks. Thus, the study consists in developing a detection module of the dysfunction for the diagnosis tool system.
Our study is interested particularly at the stage of fault detection, which precedes any stage of diagnosis, based on the application of the test of Page-Hinckley for a system of pasteurization of agro-alimentary production system.

Key Words

Fault Detection, Dependability, Diagnosis, Statistical Process Control; tests of hypotheses

1. Introduction

Generally, the increase in productivity passes through the improvement of production systems availability and the costs maintenance reduction. The systematic maintenance of these systems increases the installations standstill times. The conditional maintenance based on the continuous monitoring of the process makes it possible to optimise the downtimes. It became a major industrial stake and the faults detection is an important component of this one.
However, the physical process is complex either by the significant number of variables that it is necessary to supervise and by the multiple interrelationships which exist between them. It comprises many operating modes such as the degraded mode which emerge when failures emerge.

The breakdown detection leads to decision-makings. From the set of information available and knowledge, the question to be asked is whether the system functions correctly or not. The problem of decision thus posed is very complex although a breakdown or a failure corresponds to either a stop of the system or a modification of operation. To make such a decision will involve a loss of production for the company especially if the decision taken is due to false alarm. When monitoring a system, the detection of a fast operation modification and with a weak rate of false alarm is fundamental.

Beyond its aptitude to reduce the variability of the process in order to permanently satisfy the technical specifications of the products and to constantly improve the processes the tests of assumption present a better way to establish detection.

2. Detection

Detection is the operation that makes it possible to decide if the system is or is not in a normal structural state. It is a logical operation whose answer must be binary.
Knowing that the system throughout its environment and its operating conditions is subjected to random disturbances, the tools for detection are of statistical nature: test of (hypothesis) assumptions implies a risk of error. This risk is measured in terms of probability of giving a bad answer, and the two bad answers are the following ones:

2.1. Probability of false detection:

to detect a fault when this last does not exist. This type of error is very prejudicial because it leads to reconfigurations or stops to no purpose. Moreover, the operators and/or supervisors quickly lose confidence in detectors announcing the false breakdowns.

2.2. Probability of non-detection of the breakdown:

to omit a fault that can later on involve a breakdown. On certain systems of high level of safety (aeronautical, nuclear) the probability of non-detection must be null or almost.

The detection system must thus have arguments of adjustment making it possible to minimize these risks of error.

3. Page-Hinckley Test

There are a considerable number of statistical tests. By way of illustration, one can quote the Bayes test, which consists in calculating the likely ratio and to compare this relationship with a threshold that depends on the criterion and the probability of the assumptions. A priori, the minimal test, which consists in choosing the probabilities that make the performances as bad as possible. In the Wald test, we have instantaneously defined two thresholds and according to the value of the likely ratio compared to these thresholds one makes the decisions. The sequential test on the variance which considers that normal operation corresponds to a certain variance and a failure being characterized by an increase in this variance and the Page-Hinkley test which is a sequential adaptation of the detection of an abrupt change of the average of a Gaussian signal and the detection problem consists of running two tests in parallel, testing between the no change hypothesis:

$H_0 : r > n$

And the change hypothesis:

$H_1 : r \leq n$

The application of the Page-Hinkley test supposes firstly the knowledge of the values m_0 and m_1. In a more realistic way, one will consider that the average m_0 was known before the jump or is estimated in a recursive way from the first available values. We set then the minimal absolute value δ_m of the amplitude of the jump to be detected and the procedure consists in carrying out two tests in parallel. The first makes it possible to detect an increase in the average. We calculate then:

$$U_n = \sum_{i=1}^{n} (x_i - m_0 - \frac{\delta_m}{2}) \quad , n \geq 1 \text{ avec } U_0 = 0$$

$$m_n = \min_{0 \leq k \leq n} (U_k) \quad , n \geq 1$$

and alarm when:

$$U_n - m_n \geq \lambda$$

The second allows detecting a decrease in the average. We calculate now:

$$U_n = \sum_{i=1}^{n} (x_i - m_0 - \frac{\delta_m}{2}) \quad , n \geq 1 \text{ avec} U_0 = 0$$

$$M_n = \max_{0 \leq k \leq n} (T_k) \quad , \ n \geq 1$$

and alarm when:

$$M_n - T_n \geq \lambda$$

The decision whish is taken corresponds to the rule which stops first, and the estimate of the jump time r is the minimum of m_n (respectively the maximum of M_n) time before detection.

4. Application of the Page-Hinkley Test on the Pasteurizer

The average temperature of pasteurization under normal operation is equal to 85° C. In absence of defaults, signal of the temperature average is shown in figure 1

Under abnormal operation, this value will be modified, when it increases with an amplitude equalizes to 2 or it decreases, that means that there is a failure on the pasteurizer which can lead to a breakdown or a stop of the system and a deterioration of the milk quality. In this case, the detection of this failure and the diagnosis module starting becomes an important and urgent action.

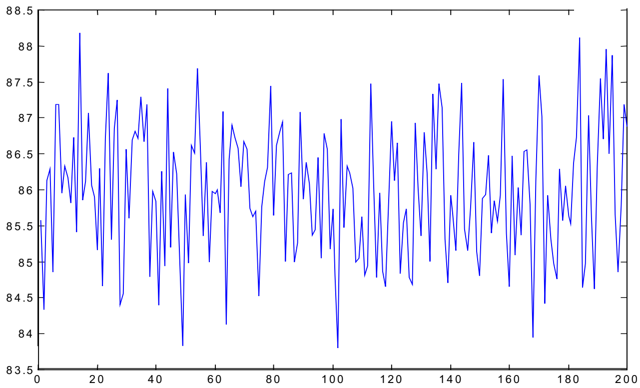
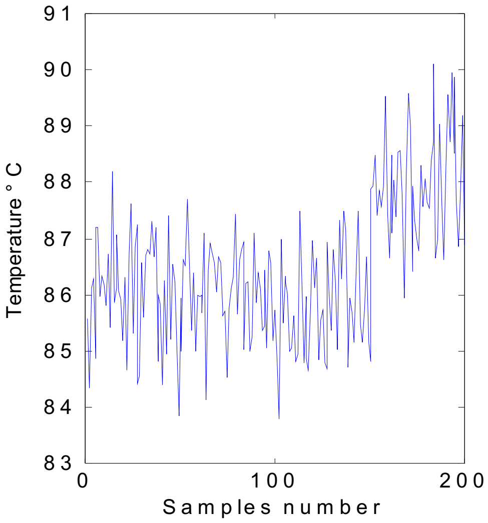


Fig. 1: Signal of the temperature average in absence of faults

5. Temperature Increase Detection

Figure 2.a represents the signal of average temperature with an average value of 90°C and of amplitude equal to 2, with a jump of the average which occurs at point 150, the average exceeds the 92°C. then this test allowed us to detect the increase in average. figure 2.b shows the evolution of the difference $U_n - m_n$ and the detection threshold λ



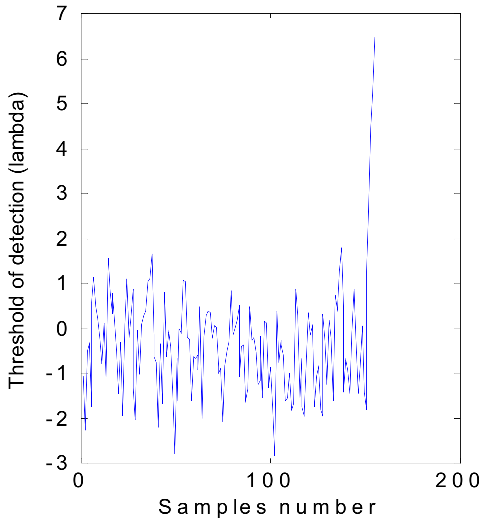
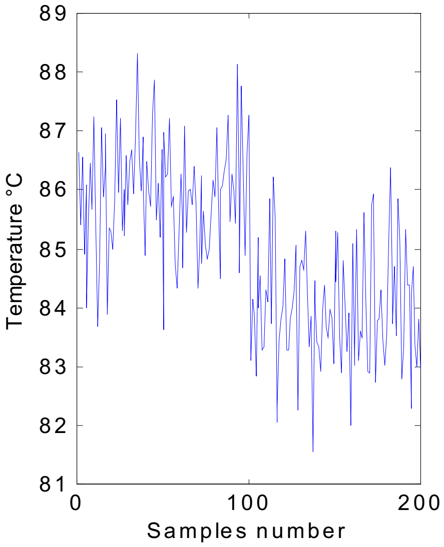


Fig 2.a: Temperature average signal with average jump at point 150
Fig 2.b: Evolution of the difference $U_n - m_n$ and the detection threshold λ

6. Temperature Decrease Detection

The figure 3 a show the temperature average signal with average jump at point 100. The figure 2.b show the evolution of the difference $U_n - m_n$ and the detection threshold λ



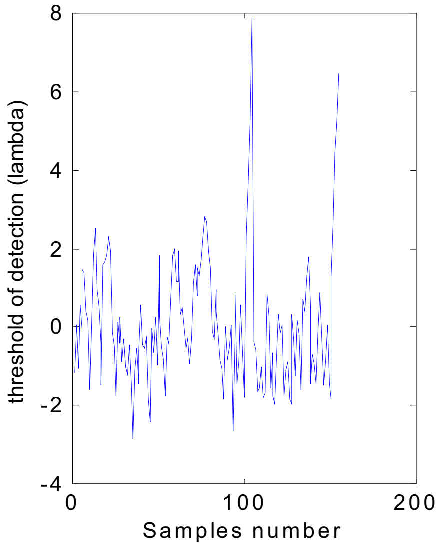


Fig 3.a Temperature average signal with average jump at point 100
Fig 3.b Evolution of the difference M_n- T_n and the detection threshold λ

7. Conclusion

A good pasteurization is always an objective to be realized. A change of state, stabilization drift, appears by an abrupt change in the pasteurization average temperature. For safety reasons, this change must be detected in an early way. The statistical tests are particularly adapted to this type of problem. The Page-Hinkley test is the test to which our application is related. It is the test that gave us the detection of the instantaneous changes in the pasteurization average temperature.

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