# Anomaly Detection Time Series

Ecole doctorale Sciences Pour l'Ingénieur

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## Introduction

The aim of this thesis is to detect anomalies in the activity of dairy cows. An anomaly can be a disease, an estrus, a perturbation in the barn, etc. A farmer needs to early detect the anomalies to act as fast as possible.

An indoor GPS placed on each cow detects their position in the barn per second. From these locations, three main activities are defined:

- **eating** if the cow was located new to the trough,
- **in alley** if the cow was located in the alley,
- **resting** if the cow was located in the cubicles.

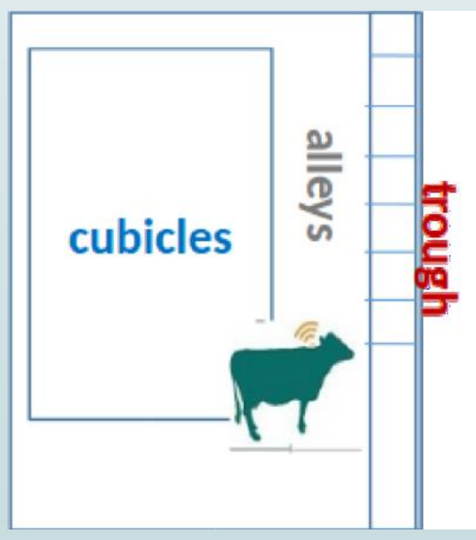

*Fig 1: Structure of a barn*

These three activities are aggregated into one single value called **level of activity**. The process is described in [1]. This activity is given for each cow and for each hour. A high value corresponds to a high activity (e.g. eating) and a low value corresponds to a low activity (e.g. resting). The problem consists of detecting anomalies in the time series representing the level of activity of each cow.

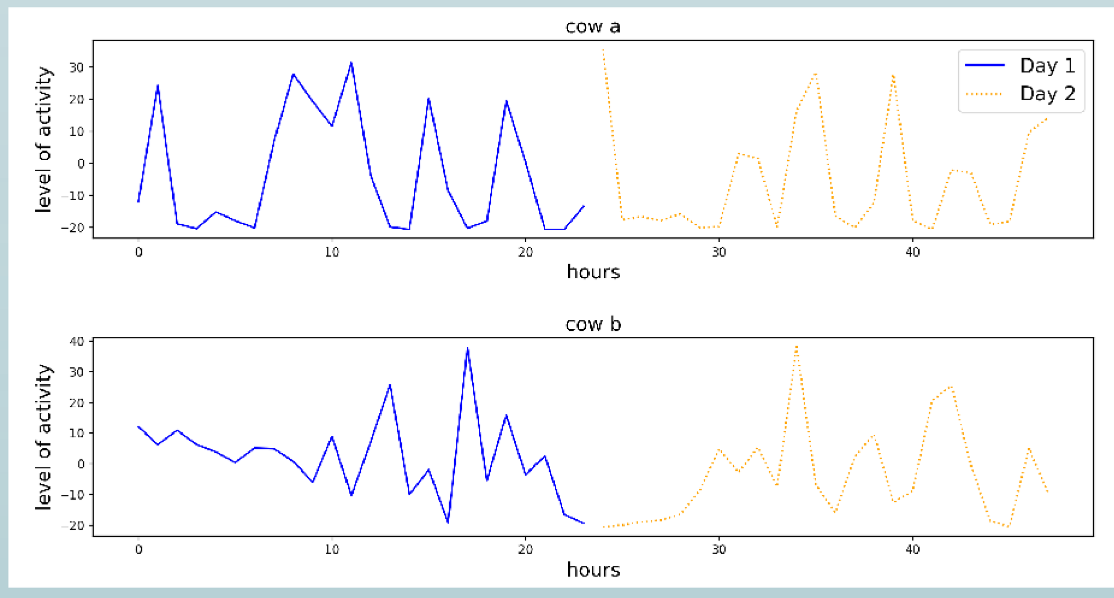

*Fig 2: Example of two levels of activity time series of two different cows for 2 days*

The Fig 2 underlines two main problems:

- two cows can have two different shapes of level of activity,
- the activity of a cow can change with time.

Consequently, it is impossible to define a pattern for a normal activity and a pattern for each type of anomaly. This excludes all the solutions based on classification tools. The proposed solution consists of analyzing the changes in the seasonal rhythm called **circadian cycle.** The method is called **Fourier Based Method** (FBM).

## Fourier Based Method

As illustrated in the Fig 3, the time series are sliced into time windows of size $p$ and delayed of $q$ ($p=24$ and $q=12$ hours in this study).

A Fast Fourier Transform is applied on each time window to obtain the harmonics $h_f$.

Then, a model $m(t)$ of each time window is Built according to:

$$m(t) = \sum_{f=-z}^{z} |h_f| \cos(2\pi f \frac{t}{p} + \arg(h_f))$$

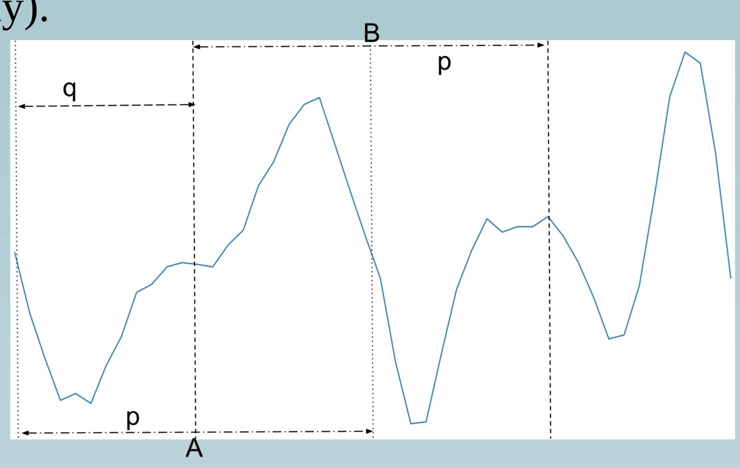

*Fig 3: Illustration of the time windows slicing operation*

with z, the number of harmonics to keep in the model. This is an important parameter that fix the precision of the model.

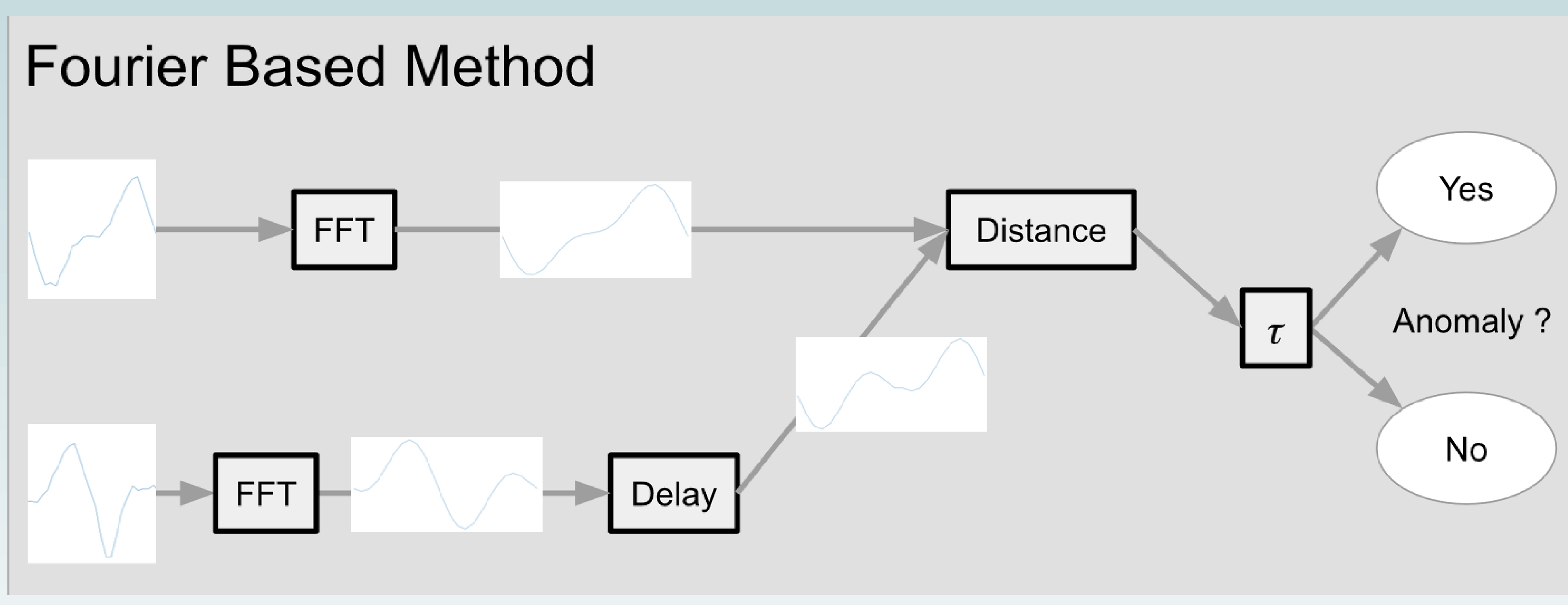

*Fig 4: General framework of the Fourier Based Method*

An anomaly is detected if two successive models $m_A(t)$ and $m_B(t)$ are **too** different. This difference is measured with a $L_1$ distance:

$$L_1 = \sum_{t=0}^{p-1} |m_B(t) - m_A(t)|$$

Notice that the model of B is delayed of $q$ hours from A. To synchronize them, a **delay** of $-\frac{q}{p}2\pi$ is added in $m_B$(t).

A **threshold** is computed and if the distance between two models is over this threshold, we consider the both models as abnormal.

## Results

To evaluate the method, we used the True Positive Rate (TPR) and the False Positive Rate (FPR) measures. The aim is having a TPR as close to 1 as possible and a FPR as close to 0 as possible.

The method is applied on data set coming from an experimental farm of INRA.

Let's focus on the lameness (Fig 5) and estrus (Fig6) anomalies.

For each, we study the influence of the $z$ value. For both anomalies the best is $z = 1$ and lameness are Better detected than estrus.

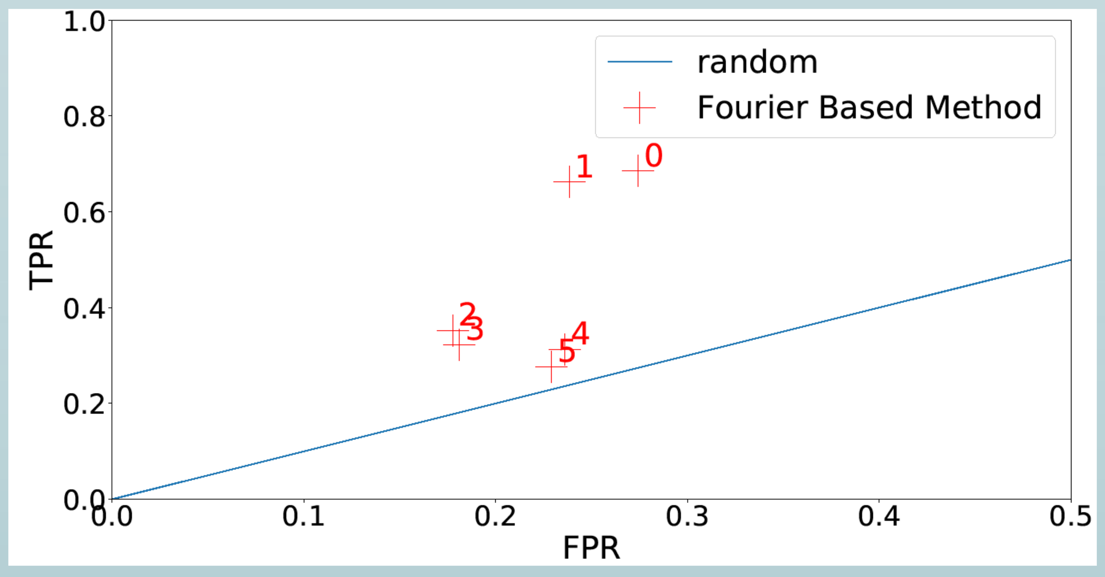

*Fig 5: Results of FBM for lameness anomaly; the numbers represent the z value*

The results are: lameness, TPR = 0.66, FPR = 0.24; estrus, TPR = 0.50, FPR = 0.24.

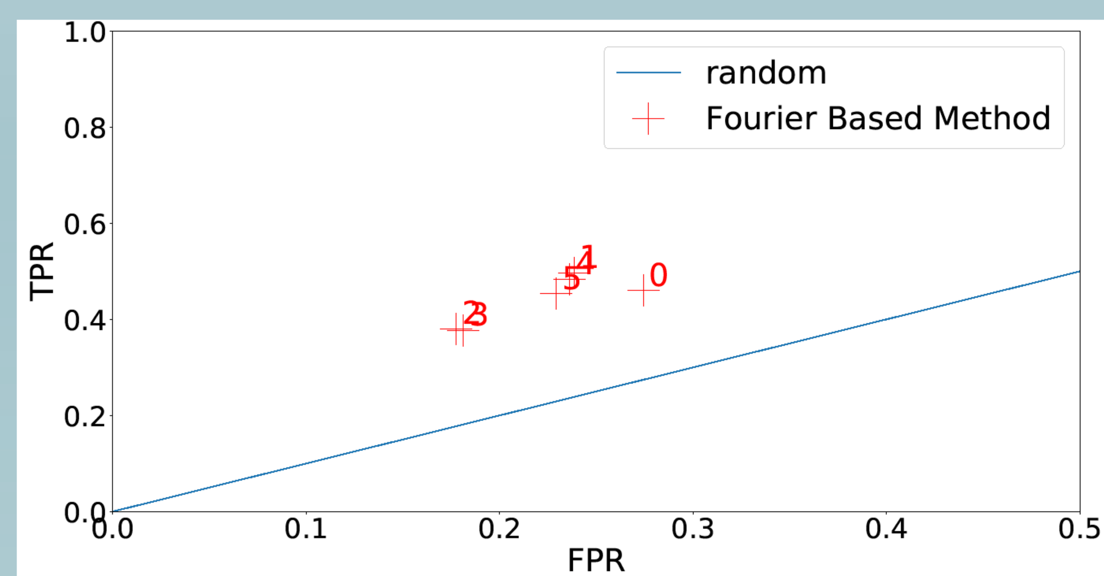

*Fig 6: Results of FBM for estrus anomaly; the numbers represent the z value*

The $z$ value acts as a filter on the model. A low value of $z$ takes the model away from the original time window but that apply a filter with a high-level of **noise reduction**.

## Conclusions

**This Fourier Based Method is able to detect anomalies in time series and it can perform without identifying the pattern of each anomaly. And other strength of this FBM is its capacity to apply a noise reduction by selecting a good value for the *z* parameter. With the tested data set, the method shows promising results [2].**

## Bibliography

1. **Isabelle Veissier, Marie-Madeleine Mialon, and Karen Helle Sloth.** ***Early modification of the circadian organization of cow activity in relation to disease or estrus*. Journal of dairy science, 100(5):3969–3974, 2017.**
2. **N.Wagner et al.,** ***Use of a precision-livestock-farming technology coupled with time series methods to identify abnormal circadian pattern of activity*, Measuring Behaviour, Jun 2018, Manchester, UK.**