Importance of Curve Fitting

Curve fitting data to a continuous math function is commonly done for the following reasons:

- interpolation and/or extrapolation of data;
- parameter estimation where derivative values are required;
- ease to 'picture' a technical problem in publications, seminars, & conferences; and,
- verifying micro-chip manufacturing processes and building of chips.

The last is relatively new and few are aware of the practice. But, while working at Memorex in the 1980s, my manager asked for a math model of an isolated pulse from reading a disc drive. A pulse model was created and used to test other circuit designs and ideas. I was given 200 disc drives to test how well the math model worked overall. 199 discs agreed pretty well to a pulse similar to that show in figure 1.2 below. But number 200, showed something never seem before; see figure 1.1. Our math model fit even this dataset well! This convinced us that the model was excellent. After thinking about this odd curve and talking amongst our selves, we concluded that the chip was defective. This finding was pointed out to the manufacturing department who were looking for a way to detect bad chips. ☺

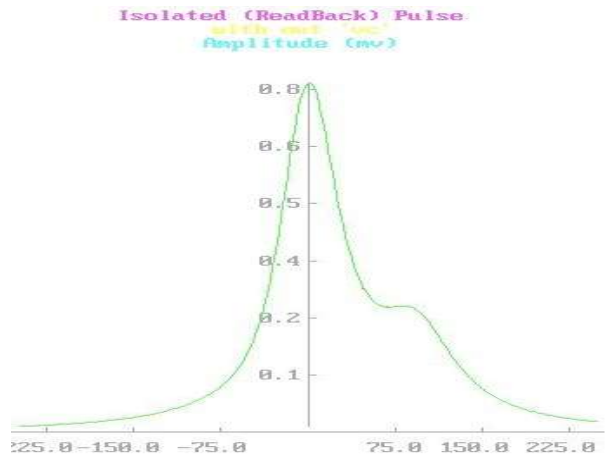

Figure.1.1 A perfect model to Odd data

Optimum pulse shape?

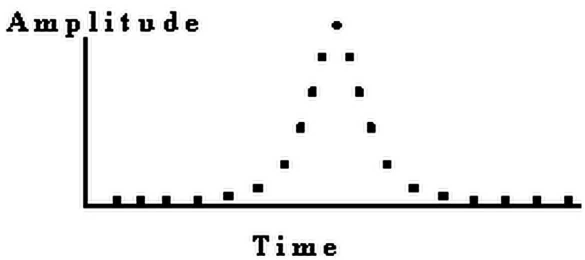

Figure 1.1 An "ideal" Readback Pulse from a disc drive

Introduction to Magnetic Recording

Curve fitting is the first type of parameter estimation problem that we will be discussing. We have two datasets retrieved from Magnetic Recording during the 1980s for what are called an Isolated (Readback) Pulse. Both these datasets had an 'okay' fit with model one, a Lorentzian series. Thus, we tried to find a better math model, a modified model. This new model converged faster than the first model. The 1st model is a symmetric model and the other is an asymmetric model.

Background of TFH Math Model for a Readback Pulse from Magnetic Recording

Magnetic recording of transitions written onto a computer disc drive may produce an isolated pulse as shown below. This pulse comes from a disc drive's read-write channel. Each transition will cause such a signal to occur.

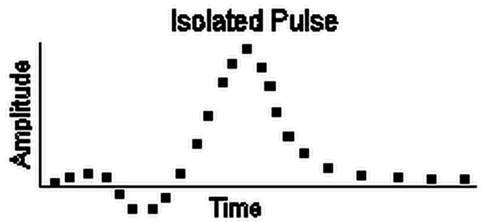

Figure 1.2 An isolated Readback Pulse from a 1980s disc drive

The signal's shape is very important to the electrical engineering development groups of disc drives. An isolated (readback) pulse should be symmetric and have a relatively fast rise time (i.e. sharp slope) for improved peak detection capability. A math model for the pulse can help gain insight into what electronic sub-system/components are causing the pulse to be asymmetric or have a slow rise time.

A Memorex physicist suggested that the longitudinal magnetic force was assumed the main contributing factor in determining a readback pulse shape, before the early 1980's. This force component was modeled by a series of three Lorentz functions. These functions have varying independent parameters that are dependent upon the drive's Thin-Film-Head (TFH) composition, size and shape. The values for these parameters were helpful in understanding a design and pinpointing any manufacturing flaws.

A Lorentz[1] function has represented/modeled an isolated readback pulse for some time. The basic Lorentz function is defined as $y=\frac{1}{1+x^2}$. The isolated pulse model is a composite of three Lorentz functions, called a **Lorentzian** series, as shown here:

$$signal_1(t)=\sum_{i=1}^{3}\frac{v_i}{1+\left(\frac{t-t0_i}{pw\_50_i/2}\right)^2}$$

Equation 1.1 **Lorentzian Series**

where v_i = Amplitude of i^{th} Lorentzian pulse;
pw_50_i = Lorentzian pulse width, measured at 50% height of v_i; and,
$t0_i$ = Origin of the i^{th} Lorentzian.

In the early 1980s, this model was found to be inadequate when Thin-Film-Heads (TFH) were starting to be used in disc drives. An examination of the math model versus actual data plots showed that the 1970s model was no longer sufficient. The longitudinal force, coupled with the

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[1] **Hendrik Antoon Lorentz** (July 18, 1853 –February 4, 1928) was one of the greatest Dutch theoretical physicists. He was the second Nobel laureate in physics, together with Pieter Zeeman. They received the prize in 1902 for the discovery (by Zeeman) and the explanation (by Lorentz) of the Zeeman effect, the splitting of spectral lines in a magnetic field. Lorentz's main contribution to physics was in the theory of electromagnetism in which he continued and extended the work of the Scotsman James Clerk Maxwell.

increased vertical force, were used to provide an excellent model for TFH readback pulses in the mid 1980s. This math model we called a **Modified Lorentzian** series, $signal_2$, as shown here:

$$signal_2(t) = \sum_{i=1}^{3} \frac{v_i + vc_i \left(\dfrac{t - t0_i}{pw\_50_i / 2} \right)}{1 + \left(\dfrac{t - t0_i}{pw\_50_i / 2} \right)^2}$$

Equation 1.2 Mod. Lorentzian Series

where v_i = Amplitude of i^{th} longitudinal magnetic force;

vc_i = Amplitude of i^{th} vertical force component;

pw_50_i = Lorentzian pulse width, measured at 50% height of v_i; and,

$t0_i$ = Origin of the i^{th} Lorentz function.

Plots showing fit to a 1980s Thin-Film-Head data using Lorentzian & Modified Lorentzian series:

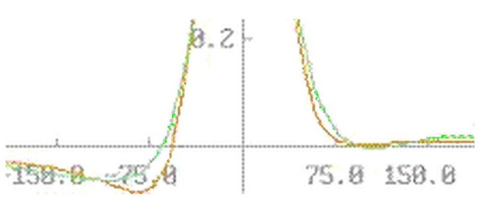

Figure 0.3a Lorentzian Series

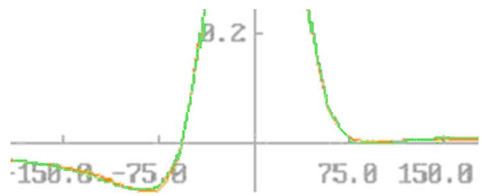

Figure 0.3b Mod. Lorentzian Series

Computer App for Solving these Problems

A Calculus-level App is available to solve this type of problem. Please download the free CurvFit App, install it, and execute some Demo files in order to get an idea of the process that one must do to solve your problem.

Optional: view source file, */od-tools/curvfit/Fit4User.fc*, in order to see the coding of the various math models available in CurvFit app.

Your Turn!

Have a Curve Fitting Problem to solve? Please, state it here and use graphs, pictures, etc. to get your problem well stated and understood by those reading it. Plus, attach your dataset so others may try their luck at solving your problem.

Do you have a model that could be added to CurvFit that may be of interest to others? If so, please state the function and mention areas where it may be of interest.