ANALYSE METHODS FOR AUDIO SIGNAL DETECTED FROM WATER LEAKAGE SPOT

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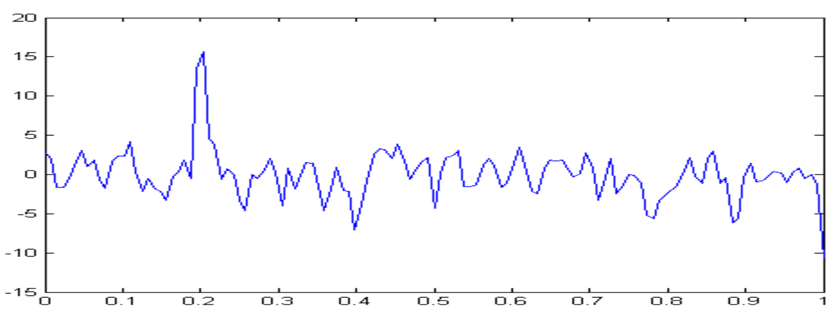
Abstract: The leakage in water pipeline wastes too much water every year. To detect water leak accurately and get more information from water leakage audio signal, we do much research for the audio signal detected by sensor.
If there is a leakage spot in pipeline, the signal detected by sensor is useful signal with certain frequency mixed with noise signal. In this paper, we discuss a series of analyse methods such as FFT(Fast Flour Transform),Wigner-Ville Distribution, Self-correlation, Wavelet Transform. We also discuss how to apply these theories to analyze the audio signal detected by sensor for many purposes.
By using above analyse methods, we have improved the ability of analyze the audio signal.
Applying the above methods discussed in this paper, we can acquire more useful signal in complex environment so that we can detect water leakage accurately.

Introduction: Underground pipeline is the lifeline of the cities. In modern society, underground pipelines play an important role. The lack of water is the serious difficulty that the human beings have to face. The key technology of underground pipeline detection is acoustic signal process. When the leakage occurs, the acoustic signal forms because of friction between water and pipeline. In the paper we do research on the methods of acoustic signal process.

Results: The results are as the followings



Figu

Figure 1: using Welch method to estimate power spectrum

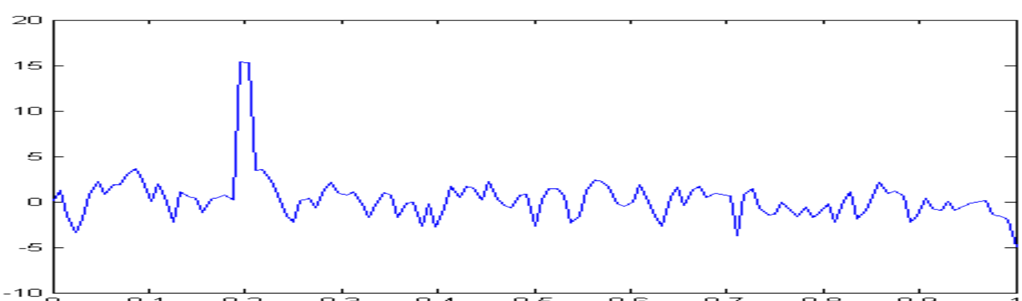


Figure 2: using multiple windows method to estimate the power spectrum

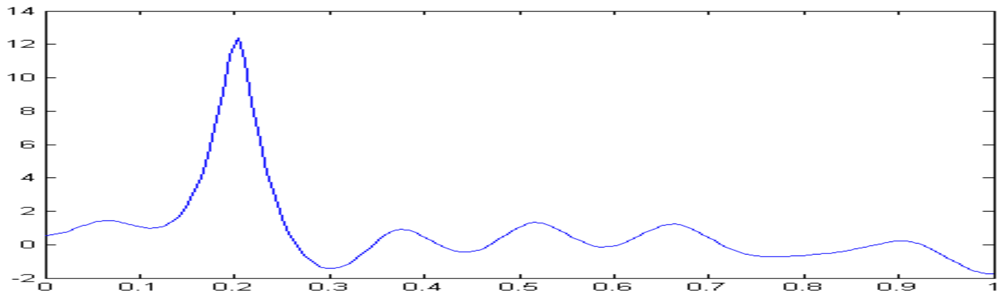


Figure 3: the result of the maximum entropy spectral estimation

Discussion: The signal P(t) picked up by sensor is acoustic signal A(t) mixed with background noise signal N(t). That is,

P(t)=A(t)+N(t)

(1-1)

Because the power spectrum of A(t) and N(t) is combined together, so it can't be separated by band pass filter . As we know, A(t) and N(t) are ergodic processes, the auto –correlation of P(t) is

$$R_p(\tau) = R_A(\tau) + R_N(\tau)$$

(1-2)

$$R_N(\tau) \xrightarrow{\tau\to\infty} 0$$

(1-3)

Because acoustic signal has certain frequency,

$$R_A(\tau) \xrightarrow{\tau\to\infty} R_P(\tau)$$

(1-4)

CCalculate the power spectrum of P(t).By observing power spectrum ,the operator can find out if the leakage spot e exists.

1.POWER SPECTRAL ESTIMATION

3.1 1.1 segmentation averaging period method

DDivide acoustic signal P(n) into M $0 \le n \le N-1$ separate segments, every segment has k sampling values, that isis

$$MK = N$$

(1-5)

Calculate the power spectrum for every segment, then take their mean as the power spectrum of the whole segment-P(n) As the M increase, the variance trends to zero, so it is gradually un-bias estimation. To keep every segment separate, select K so that $m > K$, is very small, so every segment is separate. We can also divide the whole segment into overlapping segments, Overlapped at the ratio 2:1.Estimate power spectrum for every segment. The result shows the latter dividing method is better. Although segmentation averaging periods method can reduce the estimation error and fluctuation, as a result, the resolution decrease because dividing whole segment into small segments. To improve resolution, after dividing segment P(n),utilize non-rectangle window to preprocess every small segment, then estimate the power spectrum for every small segment, calculate the mean. Adopting appropriate non-rectangle window can reduce frequency leakage, and improve resolution.

1.2Welch method

Modify the datum of P(n) with one window function, then calculate the power, then calculate the power spectrum. Besides Bartlett window function, we often use Hanning window, that is

$$w(m)\begin{cases}0.5+0.5\cos(\pi m/M), |m\le M| \\ 0,|m|>M\end{cases}$$

(1-6)

and harming window, that is,

$$w(m)=\begin{cases}0.54+0.46\cos(\pi m/M), |m|\le M \\ 0,|m|>M\end{cases}$$

(1-7)

The advantage of this method is simple algorithm. Figure 1 shows the result of Welch method

1.3 multiple windows method

This method utilizes several window functions in quadrature to estimate their separate power spectrums. Then estimate the whole power spectrum. Compared with the above two methods, this estimation has more freedom, and makes great improvement on accuracy and fluctuation. Figure 2 shows the result of multiple windows method

1.4 maximum entropy spectral estimation

This method aims at keep the information lost because of window discarding the datum out of the window so that make the entropy maximal. By applying this method we can find the following advantages:

(1) .the spectral curve is smoother

(2). high resolution

As for given signal P(n),n=0,1,…,N-1,The length of the signal auto-correlation is limited, that is m=-(N-1)~(N-1),but datum extrapolation is shielded in the algorithm, this make the length exceed the given length. Figure 3 shows the result of the maximum entropy spectral estimation.

2. LEAKAGE SPOT LOCATION

With correlation technology, the leakage spot can be located. The location method is shown in figure 4.suppose the two sensors detect the acoustic signal from leakage spot and the signal that sensor A detect is $P_A(t)$, the signal that sensor B detect is $P_B(t)$

$P_A(t) = A(t)$ +N $_A$ (t)

(2-1)

$P_B(t) = A(t+\tau) + N_B(t)$

(2-2)

N $_A$ (t) is the background noise detected by sensor A, $N_B(t)$ is the background noise detected by sensor B.

Sensor A Leakage spot
Sensor B

L1 L2

Figure 4: placing sensors along the pipeline

If there is no leakage in the pipeline, the correlation of $P_A(t)$ and $P_B(t)$, that is $R_{AB}(\tau)$, keep certain value. Once there is a leakage spot, $R_{AB}(\tau)$ varies, and it reaches the biggest when $\tau = \tau_0$. location formula can be obtained ,that is,

$$L1 = \frac{L1 + L2 - V * \tau_0}{2}$$

(2-3)

V is the speed that acoustic spreads at.

$$R_{AB}(\tau) = \lim_{T\to\infty} \frac{1}{T} \int_0^T [(A(t) + N_A(t)][(A\ (t+\tau) + N_B(t)]$$

(2-4)

Leakage signal and noise signal are separate and have no relation. So

$$R_{AB}(\tau) = \lim_{T\to\infty} \frac{1}{T} \int_0^T A(t)A(t+\tau)dt + \lim_{T\to\infty} \frac{1}{T} \int_0^T N_A(t)N_B(t)dt$$

(2-5)

If signal $N_A(t)$ and signal $N_B(t)$ have no relation at all, then the formula can be simplified as

$$R_{AB}(\tau) = \lim_{T\to\infty} \frac{1}{T} \int_0^T A(t)A(t+\tau)dt$$

(2-6)

But in fact, signal $N_A(t)$ and signal $N_B(t)$ have some relation, this need us to denoise the signals.

3.THE APPLICATION OF WIGNER-VILLE DISTRIBUTION AND WAVELET TRANSFORM AND FFT

Wigner-Ville distribution and Wavelet transform are important method to analyze the acoustic signal. They can describe the transient characteristic. The two methods have their own characteristic. Wigner-Ville distribution is easy to apply. Wavelet transform can describe the signal from multiple resolution. When the signal curve changes smoothly, adopt low resolution. and for drastic fluctuation ,adopt high resolution. so the signal can be describe more completely. Moreover, wavelet transform can be used as filter. when wavelet transform is applied ,adopting a good mother wavelet is a key problem. the author consider more importance should be attached on wavelet transform filter. FFT can be applied to accelerate the calculation of power spectrum. At the same, FFT is a method to judge if the leakage spot exist by observe the FFT spectrum. Once the FFT spectrum vibrates drastically .It can be considered there is at least a leakage spot

Conclusions: Calculating the power spectrum is the best method to detect leakage. And Correlation can be applied in location. Wigner-Ville distribution and Wavelet transform describe the transient signal well. Moreover wavelet can be applied as a filter. Appling the above combined technology, leakage detection. and location can be calculated accurately

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