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The Weak Speech-Denoising Base on Twice Sampling Stochastic Resonance

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Abstract: **In this article, we utilizing twice sampling stochastic resonance, combined with twice sampling, realized the speech-denoising of weak speech signals. The traditional speech-denoising methods treat the noise as harmful interference signal, and eliminate the noise from the noise speech signal. But in low signal-to-noise(SNR) ratio environment, it will lost very much of the speech information, or make the waveform distortion. Stochastic resonance can transfer the noise energy to the weak signal, but classic SR is only realized under small parameters in terms of the theory of adiabatic elimination, which can't using in speech-denoising. So our group using the technique of twice sampling realized the speech-denoising using stochastic resonance. The experiment result prove that this method can enhance the weak speech signals and improve initial SNR from -9 to -2.37, markedly enhance the SNR of output speech signals.**

Keywords: **stochastic resonance, twice sampling, speech denoising, signal-to-noise ratio.**

I. INTRODUCTION

In our daily life, people transmit information or communicate with each other and so on mainly through voice, so the voice is the most commonly used, convenient and effective way of communication by people. During communication, however, the speech signal inevitably will be affected by the internal or external noise interference, and then what we received is the speech signal with noise, rather than the pure original speech signal, which will disturb people in receiving information quickly and accurately. So, the scholars try to extract the purest speech signal from the noise speech signal by speech enhancement, and improve its quality in order to analysis the speech signal effectively.

According to the difference of the noise characteristics, the scholars have proposed many speech enhancement methods. At present, some of the more commonly used methods are spectrum subtraction[1], adaptive noise-suppression, wavelet transformation and Wiener filter[2] and so on. But the methods mentioned above mainly treat the noise as harmful interference signal, and eliminate the noise from the noise speech signal by noise estimation. While under the background of strong noise, the de-noising effects get worse, as they not only remove the noise but also lost part of the speech information, or make the waveform distortion.

Stochastic resonance[3] is a method of which can transfer the noise energy to weak signal, and thus it amplifies the weak signal and suppresses the noise. According to stochastic resonance theory, a new method based on adaptive stochastic resonance to extract weak speech signals is proposed. This method, combined with scale-transformation, realizes the detection of weak speech signals from strong noise[4]. By evaluating the signal-to-noise ratio of the output signal, we can adaptively adjust the parameters of the system[5], and then the weak speech signal is optimally detected. Experimental simulation analysis shows that under the background of strong noise, the output signal-to-noise ratio increases compared to the initial value. This method obviously raises the signal-to-noise ratio of the output speech signals, which gives a new idea to detect the weak speech signals in strong noise environment.

II. BISTABLE STOCHASTIC RESONANCE MODEL

Stochastic resonance is a kind of nonlinear phenomenon of non-monotonicity between the output of the physical system and the noise, the parameter of the system and the excitation signal, with the stochastic linear differential equation as the mathematical model[6]. Weak signal in strong noise interference will be synergistic with each other, so that part of the noise energy transfer to the weak signal can be two, to enhance the role of weak signals. The concept of bistable stochastic resonance can be described by the following Langevin's equation[7]:

$$\frac{dx}{dt} = ax - bx^3 + A\sin(2\pi ft) + n(t) \tag{1}$$

Where $E[n(t)] = 0,\ E[\mathrm{n(t)n(t\text{-}\tau)}] = 2\mathrm{D}\delta(\tau).$ The weak periodic signals detected in Bistable Stochastic Resonance is $A\sin(2\pi ft).$The a and b are for the bistable stochastic resonance system parameters, used to adjust the output of stochastic resonance effect; for bistable stochastic resonance system output signal. The corresponding potential function is:

$$U(x) = -\frac{1}{2}\mu x^2 + \frac{1}{4}x^4 - x(A\cos(2\pi ft) + n(t)) \tag{2}$$

The input weak signal and noise signal are stochastically resonated by the bistable stochastic resonance system, so that part of the noise energy is transferred to the weak signal, the peak of the noise is weakened and the spectral peak of the speech signal is obviously enhanced.

The classical stochastic resonance is only applicable when the signal amplitude and frequency are less than 1, and the frequency range of voice signal is 300Hz ~ 3.4kHz, so the speech signal must be processed. So we use the twice sampling to compress the speech signal , the input speech signal frequency linear compression to 0Hz ~ 1Hz to meet the adiabatic approximation conditions, and then the compressed voice signal to variable step adaptive stochastic resonance pretreatment, Finally, according to the original compression ratio of the voice signal recovery output.

Signal-to-noise ratio is an important measure of speech enhancement, which function is:

$$SNR = 10\log\frac{\sum_{n=0}^{N-1} s^2(t)}{\sum_{n=0}^{N-1}[x(t) - s(t)]^2} \tag{3}$$

Where $s(t)$ represents the pure voice signal, $x(t)$ is the output of the voice signal.

III. SIMULATION AND RESULT

We use TIMIT standard voice database in this experiment, and the sampling frequency of voice samples is 16kHz. We selected the voice sample 1, set the frequency compression ratio R = 3200, the second sampling frequency fsr = fs / R = 5. to Fig. 1.As we can see the amplitude has been normalization -1 to 1, it can make the experimental results more clear.

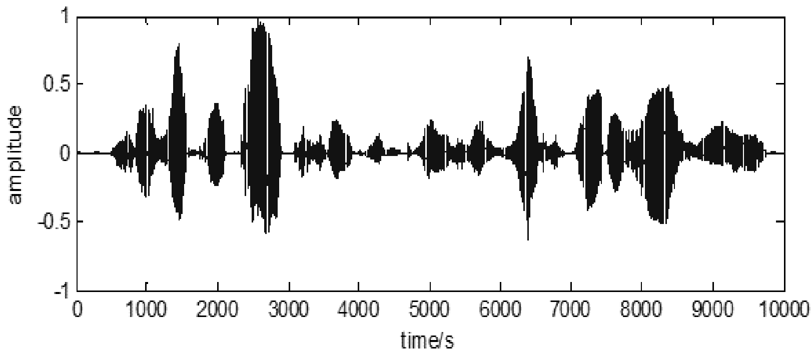

Fig. 1 The time domain waveform of pure signal after twice sampling

The Fig. 2 is the noisy speech signal superimposed on a white Gaussian noise with SNR = -5. The Gaussian white noise is selected from the NOISE 92 standard noise database. The experiments show that the speech signal is completely submerged by the noise, and it is difficult to observe the waveform of the signal.

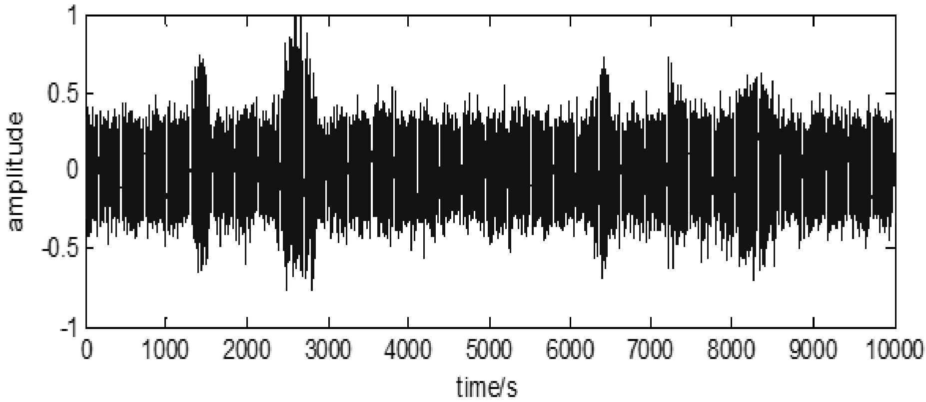

Fig. 2 The time domain waveform of noisy speech with SNR = -5

The experiment take the noisy speech signal through the bistable stochastic resonance, as to get the voice enhanced signal shown in Fig. 3, We can find that the noise is greatly reduced and the waveform of the speech signal becomes more clear than Fig.2.

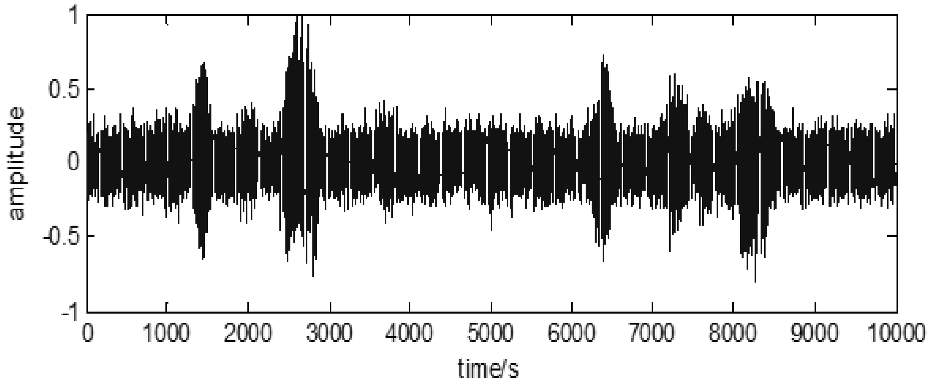

Fig. 3 The time domain waveform of noisy speech after Stochastic resonance

The SNR measurements of the input and output speech signals are also recorded. We add the pure speech superimposed initial SNR from -1 to -10 initial Gaussian white noise, with large number of experiments, recording each time the output SNR and take the arithmetic mean value in Table I. It is found that the stochastic resonance in the low SNR environment has a great noise reduction effect.

TABLE I: THE OUTPUT-SNR IN DIFFERENT INITIAL SNR

Initial SNR	**Output SNR**	**SNR gain**
-1.00	-0.28	0.72
-2.00	-0.34	1.66
-3.00	-0.51	2.49
-4.00	-0.89	3.11
-5.00	-1.15	3.85
-6.00	-1.37	4.63
-7.00	-1.71	5.29
-8.00	-2.12	5.88
-9.00	-2.37	6.63

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IV. CONCLUSION

This paper shows the new way to speech enhancement in the low signal-to-noise ratio(SNR) environment. Experiment uses the twice sampling to apply stochastic resonance to speech noise reduction, and enhance the SNR of output speech signals with a good effect. From the simulation results, it is found that the stochastic resonance apply to the intital SNR from -1 to -9, has a strong robustness. In the future, stochastic resonance could be combined with Wiener filter or some other mainstream speech enhancement methods.

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