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DEEP LEARNING BASED CHANNEL ESTIMATION FOR CHAOTIC WIRELESS COMMUNICATION

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ABSTRACT

A deep-learning-based channel estimation method for chaotic wireless communication is proposed in this letter, which is based on a deep neural network (DNN) pre-trained by the stacked denoising autoencoder (SDAE) structure. The DNN learns the channel parameters by using the autocorrelation function (ACF) of the received signal in the sense of minimizing the mean squared error (MSE). Numerical results demonstrate that the proposed scheme learns the channel very well and significantly outperforms the conventional schemes in terms of the channel estimation MSE, as well as the BER performance of the communication system. The proposed channel estimation method based on the ACF of chaotic signal is robust to the noise because of the effect of the double noise resistance operation including the autocorrelation operation and the denoising autoencoder. The proposed scheme is a blind identification method, which uses the received signal directly, by this way, saves the valuable bandwidth resource without any probe signal

I.INTRODUCTION

COMMUNICATION with chaos has attracted significant interest in the literatures [1], [2], [3], [4] since early 1990s. In recent years, more properties of chaos have been reported to be fit for wireless communication applications, such as the Lyapunov spectrum invariance property of chaotic signal after transmitted through wireless channel [5]. Chaos is proven to be the optimal communication waveform in the sense of very simple matched filter being used to achieve the maximum signal to noise ratio (SNR) [6]; the chaotic baseband waveform generated by the chaotic shape-forming filter (CSF) is proven to be topologically conjugate to the symbolic sequence [7], which means that arbitrary information sequence can be encoded into the chaotic waveform; the intersymbol interference (ISI) caused by multipath propagation can be eliminated in theory by using the proper decoding threshold [8], and the chaotic waveform can be used as the baseband signal under the conventional wireless communication system framework, in order to improve the bit error rate (BER) performance with the simpler and lower cost algorithm [9]. However, the distortion of wireless channel transmission in outdoor environment significantly degrades the performance of both the conventional wireless communication system and chaotic wireless communication system. A good channel estimation helps improving the BER performance, and making the communication system reliable. For this purpose, it is generally required to transmit a pilot sequence in the conventional estimation methods, such as the classical least squared (LS) approach, minimum mean squared error (MMSE) algorithm [10] and so on. On one hand, the conventional methods always need the pilot (training) sequence sent before the data sequence, which consumes the valuable bandwidth and reduces the data transmission rate. On the other hand, the conventional channel estimation methods are generally suffering from performance degradation due to the serious environment noise. To deal with these challenges, the autocorrelation function (ACF) property of the chaotic signal is exploited in [11], and it is used to identify the channel parameters without any pilot sequence, which improves the channel identification performance effectively. However, the blind channel identification based on ACF of chaotic signal is a complicated process by resolving a mathematical nonlinear problem. Thus, a novel solution is expected to avoid solving the complicated nonlinear equation. Due to the excellent generalization ability and powerful learning capacity of deep learning (DL) [12], it is opening up new way for the problems that are difficult to be solved by conventional methods in wireless communication [13], [14], as well as in chaotic wireless communication [15], [16], [17]. There have been many interesting results about using DL for the physical layer, including channel estimation [18], signal detection [19], etc. Among the DL applications to wireless communication systems, channel estimation is one of the most widely studied issues. Recently, the DL estimator has emerged as a promising alternative to address channel estimation problem in wireless communication systems [20] and shown excellent performance. The first attempt has been made in [21] to learn the characteristics of frequency selective wireless channels and combat the nonlinear distortion and interference for orthogonal frequency division multiplexing (OFDM) systems by applying the powerful DL methods. In [22], a novel framework incorporates DL method into massive multiple-input multiple-output (MIMO) systems to address channel estimation problems. From another viewpoint, the channel matrix is regarded as an image, the better channel estimation performance was obtained by employing a DL based image super-resolution and denoising technique in [23]. Another branch of research attempts to establish a novel endto-end deep neural network (DNN) architecture to replace all modules in communication system, instead of strengthening only certain modules [19], [24]. However, the aforementioned DL based channel estimation methods are implemented by using training data transmitted together with the information data, which increased additional bandwidth consumption. To reduce the overload and fulfill further performance improvement, it is desired to estimate the channel parameters without any pilot data by using the DL method. Different from the above DL based methods, a DNN structure with a pre-trained stacked denoising autoencoder (SDAE) is proposed to estimate the channel parameters in the chaotic baseband wireless communication system (CBWCS). In contrast to the analytical method using the ACF of chaotic signal in [11], the proposed scheme learns the channel parameters very well, meanwhile, the calculation error and the noise effect are suppressed. The contributions include: 1) A DL based channel estimation method is proposed without any pilot data, in which the pre-trained SDAE is used in the DNN structure to extract the channel state structure information from the ACF of the received signal. 2) The off-line training and online prediction mechanism is designed in the proposed DL based channel estimation scheme, in which the training time is not the application constraint, and the real time computation cost is affordable. 3) Simulation results show the efficiency and superiority of the proposed method in the sense of the smaller mean squared error (MSE) of channel estimation and BER performance, as compared to the other estimation methods.

II.LITERATURE SURVEY

S. Hayes, C. Grebogi, and E. Ott, "Communicating with chaos," Phys. Rev. Lett., vol. 70, no. 20, p. 3031, May 1993.

Control of chaos refers to a process wherein a tiny perturbation is applied to a chaotic system, in order to realize a desirable (chaotic, periodic, or stationary) behavior. We review the major ideas involved in the control of chaos, and present in detail two methods: the Ott–Grebogi–Yorke (OGY) method and the adaptive method. We also discuss a series of relevant issues connected with chaos control, such as the targeting problem, i.e., how to bring a trajectory to a small neighborhood of a desired location in the chaotic attractor in both low and high dimensions, and point out applications for controlling fractal basin boundaries. In short, we describe procedures for stabilizing desired chaotic orbits embedded in a chaotic attractor and discuss the issues of communicating with chaos by controlling symbolic sequences and of synchronizing chaotic systems. Finally, we give a review of relevant experimental applications of these ideas and techniques. A deterministic system is said to be *chaotic* whenever its evolution sensitively depends on the initial conditions. This property implies that two trajectories emerging from two different closeby initial conditions separate exponentially in the course of time. The necessary requirements for a deterministic system to be chaotic are that the system must be nonlinear, and be at least three dimensional.

The fact that some dynamical model systems showing the above necessary conditions possess such a critical dependence on the initial conditions was known since the end of the last century. However, only in the last thirty years, experimental observations have pointed out that, in fact, chaotic systems are common in nature. They can be found, for example, in Chemistry (Belouzov–Zhabotinski reaction), in Nonlinear Optics (lasers), in Electronics (Chua–Matsumoto circuit), in Fluid Dynamics (Rayleigh–Bénard convection), etc. Many natural phenomena can also be characterized as being chaotic. They can be found in meteorology, solar system, heart and brain of living organisms and so on.

Due to their critical dependence on the initial conditions, and due to the fact that, in general, experimental initial conditions are never known perfectly, these systems are instrinsically unpredictable. Indeed, the *prediction* trajectory emerging from a *bonafide* initial condition and the *real* trajectory emerging from the *real* initial condition diverge exponentially in course of time, so that the error in the prediction (the distance between prediction and real trajectories) grows exponentially in time, until making the system's real trajectory completely different from the predicted one at long times.

For many years, this feature made chaos undesirable, and most experimentalists considered such characteristic as something to be strongly avoided. Besides their critical sensitivity to initial conditions, chaotic systems exhibit two other important properties. Firstly, there is an infinite number of unstable periodic orbits embedded in the underlying chaotic set. In other words, the skeleton of a chaotic attractor is a collection of an infinite number of periodic orbits, each one being unstable. Secondly, the dynamics in the chaotic attractor is ergodic, which implies that during its temporal evolution the system ergodically visits small neighborhood of every point in each one of the unstable periodic orbits embedded within the chaotic attractor.

A relevant consequence of these properties is that a chaotic dynamics can be seen as shadowing some periodic behavior at a given time, and erratically jumping from one to another periodic orbit. The idea of controlling chaos is then when a trajectory approaches ergodically a desired periodic orbit embedded in the attractor, one applies small perturbations to stabilize such an orbit. If one switches on the stabilizing perturbations, the trajectory moves to the neighborhood of the desired periodic orbit that can now be stabilized. This fact has suggested the idea that the critical sensitivity of a chaotic system to changes (perturbations) in its initial conditions may be, in fact, very desirable in practical experimental situations. Indeed, if it is true that a small perturbation can give rise to a very large response in the course of time, it is also true that a judicious choice of such a perturbation can direct the trajectory to wherever one wants in the attractor, and to produce a series of *desired* dynamical states. This is exactly the idea of targeting.

The important point here is that, because of chaos, one is able to produce an infinite number of desired dynamical behaviors (either periodic and not periodic) using *the same* chaotic system, with the only help of *tiny* perturbations chosen properly. We stress that this is not the case for a nonchaotic dynamics, wherein the perturbations to be done for producing a desired behavior must, in general, be of the same order of magnitude as the unperturbed evolution of the dynamical variables.

The idea of chaos control was enunciated at the beginning of this decade at the University of Maryland [1]. In Ref. [1], the ideas for controlling chaos were outlined and a method for stabilizing an unstable periodic orbit was suggested, as a proof of principle. The main idea consisted in waiting for a natural passage of the chaotic orbit close to the desired periodic behavior, and then applying a small judiciously chosen perturbation, in order to stabilize such periodic dynamics (which would be, in fact, unstable for the unperturbed system). Through this mechanism, one can use a given laboratory system for producing an infinite number of different periodic behavior (the infinite number of its unstable periodic orbits), with a great flexibility in switching from one to another behavior. Much more, by constructing appropriate goal dynamics, compatible with the chaotic attractor, an operator may apply small perturbations to produce any kind of desired dynamics, even not periodic, with practical application in the coding process of signals.

It is reasonable to assume that one does not have complete knowledge about the system dynamics since our system is typically complicated and has experimental imperfections. It is better, then, to work in the space of solutions since the equations, even if available, are not too useful due to the sensitivity of the dynamics to perturbations. One gets solutions by obtaining a time series of one dynamically relevant variable. The right perturbation, therefore, to be applied to the system is selected after a learning time, wherein the dependence of the dynamics on some external control is tested experimentally. Such perturbation can affect either a control parameter of the system, or a state variable. In the former case, a perturbation on some available control parameter is applied, in the latter case a feedback loop is designed on some state variable of the system.

The first example of the former case is reported in Ref. [1]. Let us draw the attention on a chaotic dynamics developing onto an attractor in a D-dimensional phase space. One can construct a section of the dynamics such that it is perpendicular to the chaotic flow (it is called Poincaré section). This (D−1)-dimensional section retains all the relevant information of the dynamics, which now is seen as a mapping from the present to the next intersection of the flow with the Poincare' section. Any periodic behavior is seen here as a periodic cycling among a discrete number of points (the number of points determines the periodicity of the periodic orbit). Since all periodic orbits in the unperturbed dynamics are unstable, also the periodic cycling in the map will be unstable. Furthermore, since, by ergodicity, the chaotic flow visits closely all the unstable periodic orbits, this implies that also the mapping in the section will visit closely all possible cycles of points corresponding to a periodic behavior of the system. Let us then consider a given periodic cycle of the map, such as period one. A period one cycle corresponds to a single point in the Poincaré section, which repeats itself indefinitely. Now, because of the instability of the corresponding orbit, this point in fact possesses a stable manifold and an unstable manifold. For stable (unstable) manifold we mean the collection of directions in phase space through which the trajectory approaches (diverges away from) the point geometrically. The control of chaos idea consists in perturbing a control parameter when the natural trajectory is in a small neighborhood of the desired point, such that the next intersection with the Poincaré section puts the trajectory on the stable manifold. In this case, all divergences are cured, and the successive natural evolution of the dynamics, except for nonlinearities and noise, converges to the desired point (that is, it stabilizes the desired periodic behavior). Selection of the perturbation is done by means of a reconstruction from experimental data of the local linear properties of the dynamics around the desired point.

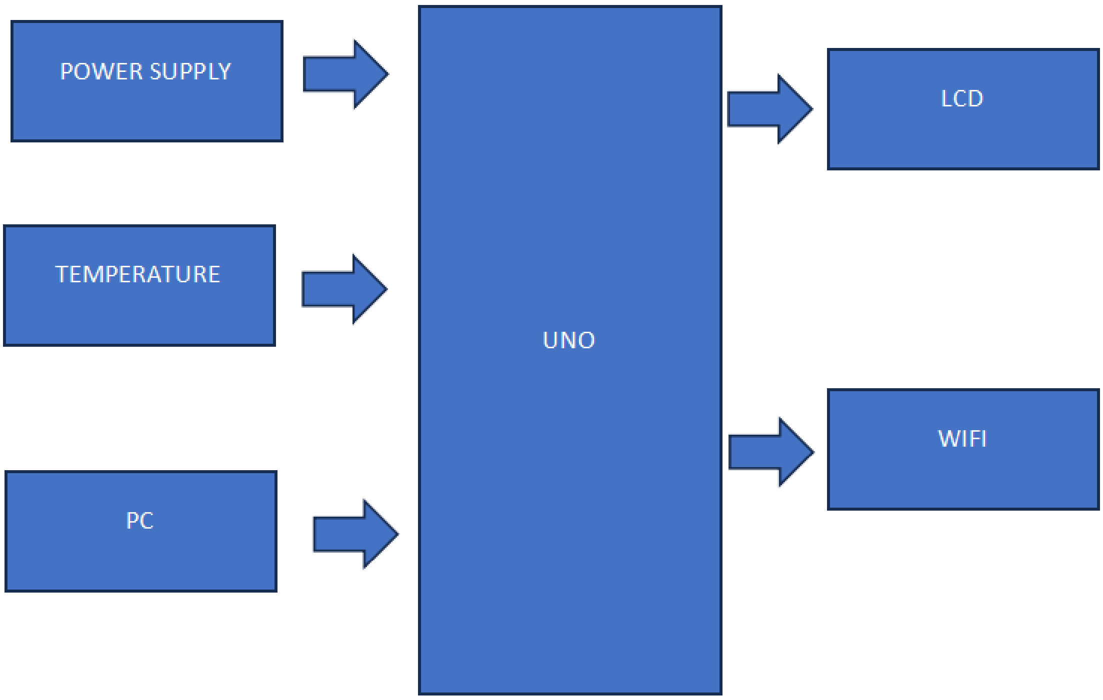
III.EXISTING SYSTEM

Nowadays confidential data transfer is a crucial task in many multinational companies, military departments, intelligence and surveillance departments, and so on. In such departments and companies lots of efforts are put forth for securing confidential data. Therefore, they need Data encryption and decryption for their applications. An example, which is given below describes data encryption and decryption to secure data using Zigbee wireless communication technology for short and long distances. With help of many encryption and decryption techniques we can achieve the goal of secure communication.

IV.PROPOSED SYSTEM

Everyone in this world wants to be safe and secure. When it comes to the safety and security of Multinational companies, Military, Army, the situation becomes more complicated. Even a common man puts his maximum efforts to protect his data. One of the popular methods to protect the data in a more secure way is to encrypt the data while sending and when received, decrypt the data to retrieve the original message. Before transmitting the data, the data will be converted into an unreadable form and will be sent. At the receiving end, the reverse of encryption carries on to get back the original message. Thus the data will be protected in every way by following the encryption and decryption standard formats. Wireless makes this project more flexible. Standard algorithms require software to be installed into the system before actually using them and hardwired connections. The hardware connections and cabling can be completely eliminated in this project

Block diagram



V.CONCLUSION

To summarize, a novel channel estimation scheme using the DNN with pre-trained SDAE is proposed in this letter, which is based on the ACF property of the chaotic baseband signal generated by the CSF. The strong noise reduction and generalization abilities of SDAE make the channel estimation MSE performance and the corresponding BER performance of CBWCS better than that using the same DNN structure without pre-trained SDAE, as well as present superior performance than those of the blind ACF analytical method, and the conventional non-blind LS method using chaotic driven signal. Moreover, by using off-line training mechanism, the computational complexity is a less

concern, which is beneficial to the real-time communication applications.

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