Multiplexing of Discrete Chaotic Signals in Presence of Noise

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In this paper, two new methods for multiplexing multiple discrete chaotic signals in the presence of noise are proposed. Existing methods are based on chaotic synchronization which is susceptible to noise and parameter mismatch. Furthermore, these methods fail for multiplexing multiple discrete chaotic signals. Our methods are based on the principle of symbolic sequence invariance [1] in the presence of noise and finite precision implementation of finding the initial condition of an arbitrarily long symbolic sequence of a chaotic map.

Multiplexing of signals is a very important requirement in most communication systems. Consider the scenario where there are multiple signals from multiple senders to be transmitted to multiple receivers, but there exists only one communication channel that can transmit only one signal at any given time. In such a scenario, it would be beneficial if all the signals are “added” in a special way to create a single composite signal for transmission across the communication channel. This single composite signal is “separated” to the respective signals in a lossless fashion at the other end of the channel. Note that there is also noise which is invariably added at the channel. This scenario can also occur in transmission of neuronal signals from different parts of the brain to various parts of the body through a single channel.

For linear communication systems, standard ways such as frequency division multiplexing and time division multiplexing are used to increase the information capacity of the channel. Non-linear chaotic oscillators are increasingly being used in communications since it offers a potential advantage over conventional classical methods in terms of noise performance. Multi-user chaotic communications has become a hot topic of research in recent times. It is also potentially useful in spectrum-spreading communication systems.

There has been some work in multiplexing chaotic signals. For the first time in 1996, multiplexing of chaos using chaotic synchronization was investigated in a simple map and an electronic circuit model by Tsimring and Sushchik [2]. Liu and Davis [3] used a scalar signal to simultaneously synchronize two different pairs of chaotic oscillators. They called this method as dual synchronization. However, there are several limitations of this method. They derive a condition for dual synchronization which holds only for certain discrete chaotic signals (maps) and for certain values of the coupling coefficients. The notable omission is the binary map (Bernoulli shift). They show that the binary map does not satisfy the condition for dual synchronization for any value of the coupling coefficients. Thus, chaotic signals from the binary map can’t be multiplexed by their method. Another limitation is that their method can only work with two chaotic signals. It is not known whether the method can be extended to multiple signals (more than two) from different maps.

A serious limitation of these methods is that chaotic synchronization is susceptible to noise and to parameter mismatch. Even one percent of parameter mismatch leads to 8% of synchronization error and one percent of noise results in a synchronization error of 4% as reported by [3].

We propose two novel methods of multiplexing multiple discrete chaotic signals without using chaotic synchronization for the two scenarios depicted in Figure 1 (we demonstrate for 10 and 24 chaotic signals respectively). Compared to existing methods of multiplexing discrete chaotic signals, our methods are significantly superior in all respects. The newly proposed methods can handle multiple signals from multiple maps (including Bernoulli shift or the binary map which was not possible by the method of Liu and Davis), completely robust to parameter mismatch and good noise resistance capability.

Figure 1: Multiplexing of chaotic signals in the presence of noise. We provide novel methods for both scenarios.