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GENERATION OF DYNAMIC CHAOTIC SIGNALS USING GENERATIVE ADVERSARIAL NETWORKS

Deterministic dynamic chaotic signals reflect the almost unpredictable dynamical behavior based on simple nonlinear rule [1]. Chaotic signals are successfully used as carriers in analog and digital communication systems [2], [3]. Chaotic modulation is an efficient wideband keying scheme. It performs as a spread spectrum telecommunication system. Ergodic Chaotic Parameter Modulation (ECPM) is one of such keying schemes. A modulation scheme determines how bits are mapped to the bifurcation parameter of transmitted signals. It requires sophisticated demodulation algorithms that increase the demodulator complexity. The demodulation of chaotic signals with deep learning techniques is presented in [4].

This paper presents the generation of dynamic chaotic-like signals using Generative Adversarial Networks (GANs). GANs are a class of machine learning models used for generating new data that is similar to a given dataset. They consist of two neural networks that are trained simultaneously in a competitive manner. The two networks in a GAN are a generator and discriminator. The generator is to create fake data that mimics the real data distribution. It takes random as input and generates a signal as output. The discriminator's job is to distinguish between real signal from the actual dataset, and fake signal produced by the generator. It outputs a probability of whether a given input is real or fake.

This research is dedicated to the signals generated with the logistic map (2). The logistic map is a simple rule that can generate chaotic behavior. Logistic map-based applications are widely used in various fields like digital communications, cybersecurity, etc.

The logistic equation:

$$\frac{dx}{dt} = r\,x\left(1-x\right), \tag{1}$$

replacing the logistic equation (1) with the quadratic recurrence equation:

$$x_{n+1} = r\,x_n\left(1-x_n\right), \tag{2}$$

where r is a positive constant gives the logistic map. Chaotic signals in this research are generated with the logistic map using Eq. 2.

Fig. 1 and 2 present the structure of the generator model and the discriminator respectively, Fig. 3 shows the example of generated by the GAN signal for *r* value of 3.9.

Layer (type)	Output Shape	Param #
dense_6 (Dense)	(None, 64)	6,464
leaky_re_lu_4 (LeakyReLU)	(None, 64)	0
dense_7 (Dense)	(None, 128)	8,320
leaky_re_lu_5 (LeakyReLU)	(None, 128)	0
dense_8 (Dense)	(None, 128)	16,512

Figure 1 – Architecture of generator

Layer (type)	Output Shape	Param #
flatten_1 (Flatten)	(None, 128)	0
dense_9 (Dense)	(None, 128)	16,512
leaky_re_lu_6 (LeakyReLU)	(None, 128)	0
dense_10 (Dense)	(None, 64)	8,256
leaky_re_lu_7 (LeakyReLU)	(None, 64)	0
dense_11 (Dense)	(None, 1)	65

Figure 2 – Architecture of discriminator

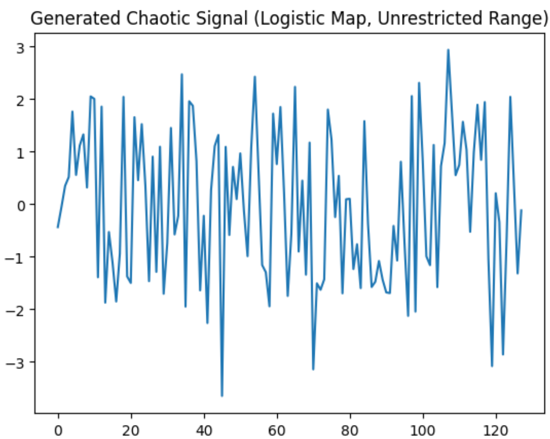

Figure 3 – Chaotic signal generated with GAN

One of the possible application areas for the developed model is digital communication with autonomous mobile robots, in line with our previous research [5]-[7].

In terms of future research, it would be useful to extend the current findings by examining the ability of external classification model to make distinction between true chaotic signals and ones generated with the GAN. Also, it would be useful to research the ability of unsupervised machine learning approach in the context of this task.

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