Literature review on topic «Chaos optical communication»

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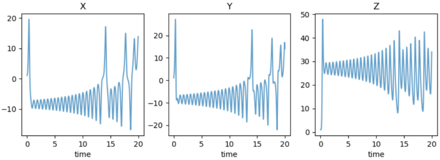
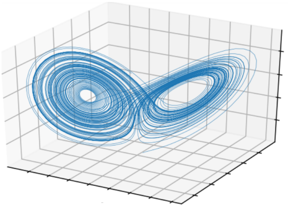
Definition of dynamic chaos

Map[1] f is **chaotic**, if

- Periodic points are dense everywhere in $\boldsymbol{E}$.
- Orbits are mixed (almost):
  let $U_1, U_2 \subset \boldsymbol{E}$. $\forall x_0 \in U_1 \; \exists N \in \mathbb{N} : f^N(x_0) \in U_2$.
- f Sensitive to the i. c.
  $\forall x_0 \in \boldsymbol{E}, \; \forall U_\varepsilon(x_0) \; \exists y_0 \in U_\varepsilon, \exists N \in \mathbb{N}\colon |f^n(x_0) - f^n(y_0)| > \beta$.





[1] W. Hirsch, S. Smale, Introduction to Chaos.

Sensitivity to initial conditions

Example of sensitivity to initial conditions with map

$$x_{n+1} = rx_n(1 - x_n), \qquad r \in (0, 4]$$

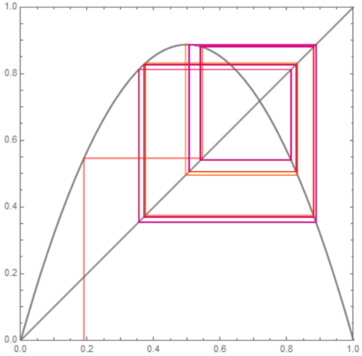


Figure 1: $r = 3.55$

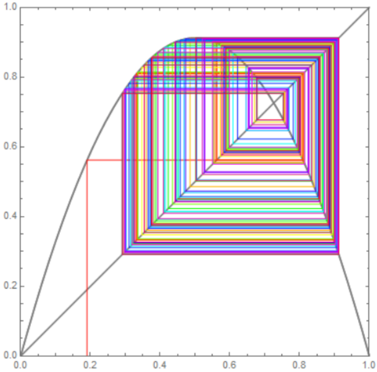


Figure 2: $r = 3.65$

Initial ideas

Consider[2] an autonomous n-dimensional dynamical system:

$$\dot{u} = f(u) \;\Leftrightarrow\; \begin{cases} \dot{v} = g(v, w), \\ \dot{w} = h(v, w) \end{cases} \quad \text{where} \quad \begin{array}{l} v = (u_1, \ldots, u_m) \\ w = (u_{m+1}, \ldots, u_n) \end{array}$$

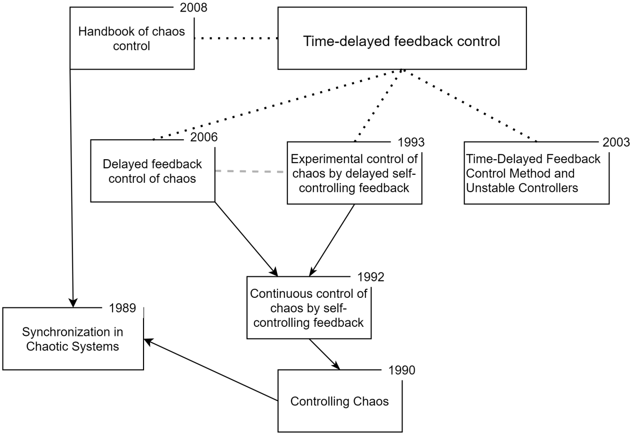
and $g = (f_1(u), \ldots, f_m(u)),\; h = (f_{m+1}(u), \ldots, f_n(u))$.
Then, at system $\dot{w}' = h(v, w')$ it's right that

$$\lim_{t\to\infty} \left(\Delta w = w' - w\right) = 0, \quad \text{only if} \;\; \mathrm{LyapunovExponent}(w) < 0.$$

Also, it could be shown, that with noize in system parametrs $\Delta w(t) \to \mathrm{const}$ at some additional conditions.

[2] M. Pecora, L. Carroll, Synchronization in Chaotic Systems, 1990.

Some articles



Greece realization

The use of such encryption on a commercial scale is possible[3]

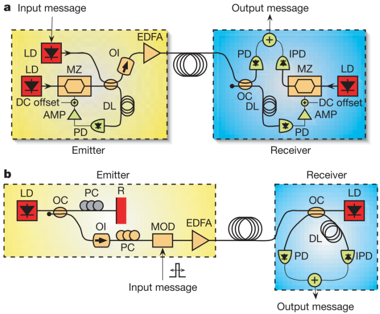


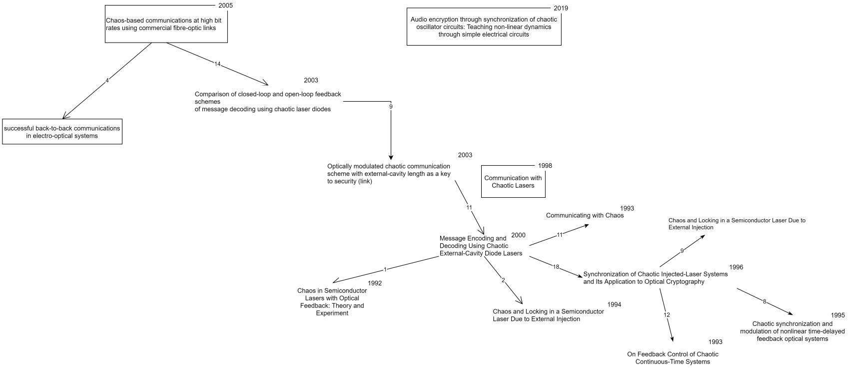
Figure 3: Two schematic set-ups for optical chaos communication

Possible realisatios:

- optoelectronic scheme (a)
- all-optical scheme (b)

[3] A. Argyris, D. Syvridis, Chaos-based communications at high bit rates using commercial fibre-optic links.

Some articles



Chaotic Circuit

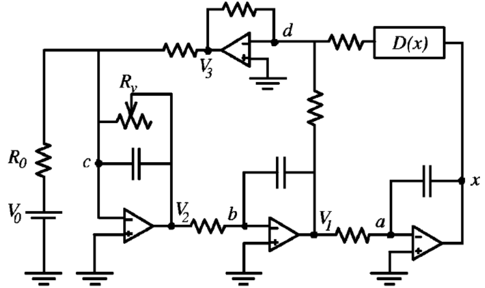


Figure 4: Schematic diagram of the circuit used.

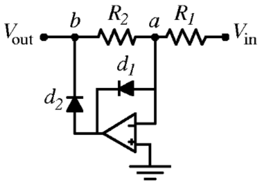


Figure 5: Nonlinear subcircuit D(x). $V_{\text{out}} = D(V_{(in)}) = -(R_2/R_1)\min(V_{\text{in}}, 0)$.

$$RC\frac{dV_2}{dt} = -\left(\frac{R}{R_v}\right)V_2 - \left(\frac{R}{R_0}\right)V_0 - V_3. \qquad (1)$$

Chaotic equation

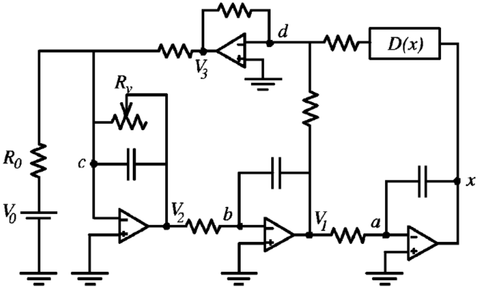


Figure 6: Schematic diagram of the circuit used.

$$V_1 = -RC\frac{dx}{dt} = -\dot{x}$$
$$V_2 = -RC\frac{dV_1}{dt} = \ddot{x}$$
$$V_3 = -V_1 - D(x)$$

$$\dddot{x} = -\left(\frac{R}{R_v}\right)\ddot{x} - \dot{x} + D(x) - \left(\frac{R}{R_0}\right)V_0. \qquad (2)$$

Chaotic Results

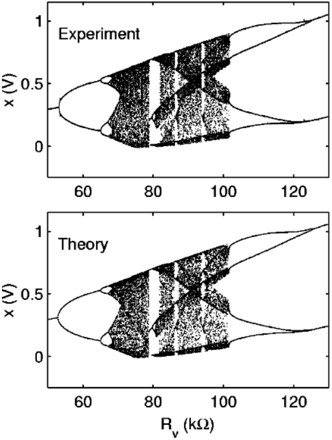


Figure 7: Bifurcation plots of the circuit.

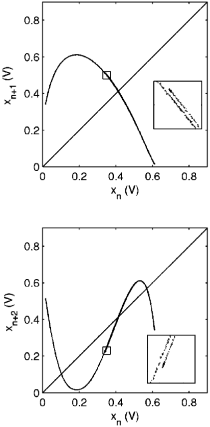


Figure 8: Experiential coupling for $R_v - 72.1$ kΩ.

To the Further Article

- «Precision measurements of a simple chaotic circuit»
  Ken Kiers and Dory Schmidt, J. C. Sprott
  DOI: 10.1119/1.1621031 27 August 2003

$$\Downarrow$$

- «Audio encryption through synchronization of chaotic oscillator circuits: Teaching non- linear dynamics through simple electrical circuits»
  Keyur Mistry, Sudeshna Dash, and Siddharth Tallur
  American Journal of Physics 87, 1004 (2019); doi: 10.1119/10.0000024

Chaotic Synchronization

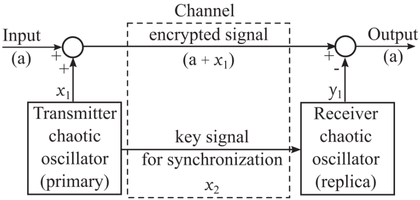


Figure 9: Block diagram of audio encryption scheme using chaotic oscillators.

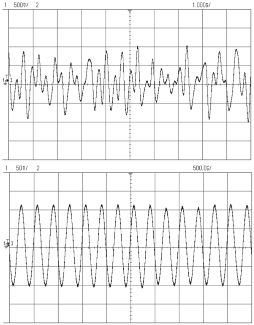


Figure 10: Modulated recorded audio signal unsynchronized and synchronized.

Nonlinearity in Wavelength

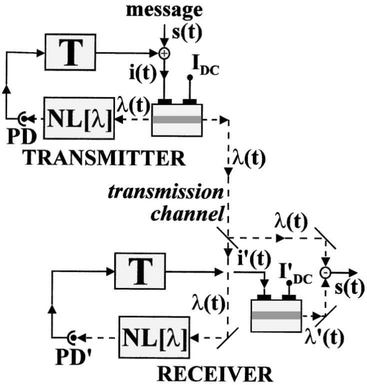


Figure 11: chematic diagram of the cryptosystem. NL stands for the nonlinear $F(\Lambda)$.

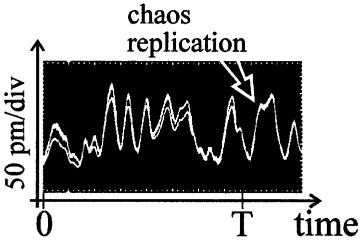


Figure 12: Evolution to the synchronization of the two chaos $\lambda(t)$ and $\lambda'(t)$.