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Optical system recognition via topological methods

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The aim is to create a **topological mode**l for the **detection** and recognition of **hidden** optical **surveillance systems**. The model is based on **fractal insights** about the **structure of the optical signal** and determination of the fractal dimension intensity distribution in a cross-sectional plane of the laser pulse reflected from the target. It is shown that the approximation of the fractal dimension value to unity is a prerequisite to the target classification as an optical surveillance device. In order to classify the type of an optical device along with the fractal dimension the group of the fractal characteristics, consisting of the type of fractal signatures, the type of spatial spectrum and the values of spatial frequency that characterize the signal structure must be developed

METHODOLOGY

There are the group of popular topological instruments that have demonstrated the high effective in the study of complex systems and optical signals. In the frame of nonlinear metrology (NM) such instruments as **Lapunov exponents**, **Shannon and Kolmogorov entrop**y, **attracto**r and **fractal dimension** can be applied.

Lyapunov exponents are used for study the dynamics of a system in the vicinity of an arbitrary trajectory. They characterize the degree of stretching and contraction of the phase portrait along the selected phase trajectories.

If the two close trajectories $x_i(t)$ and $x_{i+1}(t)$ are chosen so that $x_{i+1}(t) = x_i(t) + \xi(t), \xi(0) = \varepsilon, \varepsilon \to 0$ that the next function:

$$\Xi\left[\xi(0)\right] = \lim_{t\to\infty}\frac{1}{t}\ln\left[\frac{\xi(t)}{\xi(0)}\right]$$

takes a finite series of the Lyapunov exponents $\{\lambda_i\}, i = 1, 2, ... n$, the totality of which forms the Lyapunov spectrum.

For topological analysis of the systems the Shannon (H-entropy) and the Kolmogorov-Sinay (K-entropy) are used. H-entropy (or information entropy) is one of the key concepts of the information theory.

For a system that can be in the states X_i with probability distribution density $p(X_i)$ Shannon entropy is defined as:

$$H = -\sum_{i=1}^{N} p(X_i)\ln p(X_i)$$

The fractal dimension is a main characteristic of such structure as a fractal. According to B. Mandelbrot, a fractal can be defined as an object for which the Hausdorff-Besicovitch dimension (the fractal dimension D) strictly exceeds the topological dimension.

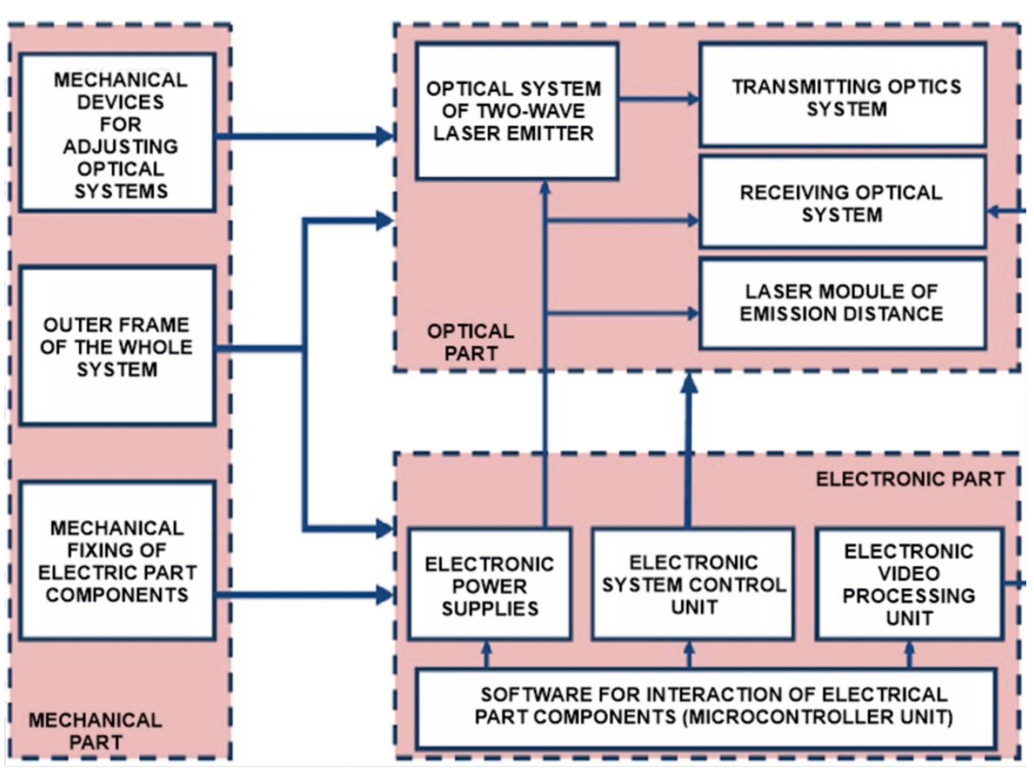
Fractal signs can be found in the structure of signals and fields, behavior of functions that evaluate the distribution of physical quantities in time and space during the physical research. It follows that it would be possible to search for a fractal dimension as a special characteristic of processes or images.

The fractal dimension for both the entire observation interval or its selected areas as well as to determine the dynamic characteristic of x for both selected time spans or during the observation time on the whole. To classify the dynamics of x, a fractal scale is created with points $1, 1.5, 2$: at $D = 1$ when the dynamics of x is strictly determined; at $D = 2$ $(D = 2 - H)$, when the value of x behaves in a regular manner, but the range of the measured values is very large; at $D = 1.5$ the dynamics of x is random. If $1 < D < 1.5$ or $1.5 < D < 2$, then the process in question is non markovian, random, persistent and antipersistent, respectively.

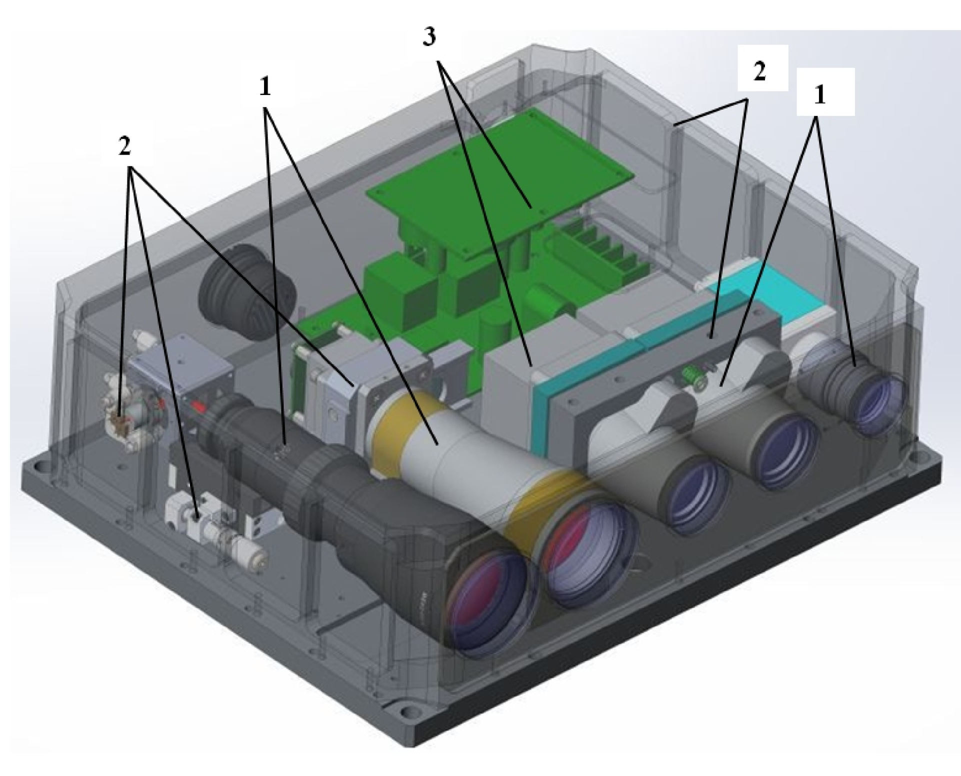
The intensity distribution in the interference image is approximated as: $I_{Int}(x) = I_0\cos^2(kx)$

The fractal dimension is not the only tool of fractal analysis and it is capable of answering a limited range of issues; in the framework of the general task is the recognition of OSD. It is not enough to address the issue of OSD type. The group of the fractal characteristics of a specific OSD must be developed in order to recognize and classify OSD. Fractal characteristics together with the fractal dimension must include the type of fractal signatures, the type of spatial spectrum and the values of spatial frequency that characterize the signal structure.

RECOGNITION SYSTEM OF OSD



Block diagram of the OSD recognition system



The general structure of OSD recognition system: 1 – the optical part elements; 2 – the mechanical part elements; 3 – the electronic parts.

The laser radiation from the source (probe beam) gets into the lens of the OSD. Some part of the incident laser radiation is reflected from the lens's anti-reflection film and returns to the system. The recognition system of OSD uses laser emitters in the near-IR range (780 nm, 808 nm. 850 nm, 905 nm, or 1064 nm) to ensure that the operator of OSD could not see that he was detected. Note that the human eye has almost zero sensitivity to radiation with a wavelength of more than 700 nm. This wavelength is actually used in laser optics detection systems in order to be invisible.

Integration of an infrared camera in the recognition system of OSD allows us to see an intense spot of light on a computer screen or a display and to record an optical device and the like. The laser unit for distance measurement and the unit for determining the coordinates of the reflected signal (equipped with a magnetic compass and a GPS receiver) make it possible to determine the distance to the OSD and its coordinates. The topological recognition model developed by the authors (6) – (15) allows identifying the type of OSD.

CONLUSIONS

- The topological model for the detection and recognition of hidden optical surveillance systems has been presented. The model is based on fractal insights about the structure of the optical signal and determination of the fractal dimension intensity distribution in a cross-sectional plane of the laser pulse reflected from the target. It is shown that the approximation of the fractal dimension value to unity is a prerequisite to the target classification as an optical surveillance device.
- In order to classify the type of an optical device along with the fractal dimension the group of the fractal characteristics, consisting of the type of fractal signatures, the type of spatial spectrum and the values of spatial frequency that characterize the signal structure must be developed.
- Recognition system of optical surveillance devices is based on the topological model of optical surveillance devices recognition. It allows measuring the distance and coordinates of a target as well as recognizing it.

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