***Institute for Information Transmission Problems***

# LABORATORY 1

## *Laboratory of Information Transmission and Control Theory*

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## DIRECTIONS OF ACTIVITY:

- the development of the mathematical models, methods and algorithms for the protection of the information networks;
- the development methods of the algebra and information theory for the construction of the diagnostic built-in system;
- the study of limit behavior of solutions of non-autonomous non-linear evolution equations, investigations of trajectory;
- attractors of partial differential equations, their structure and dependence on parameters, constructions of integral manifolds with exponential tracing;
- source coding and data compression;
- the problem of asymptotically optimal universal coding to relative redundancy creation;
- nonparametric estimation: adaptive estimation in partial linear models, statistical approach to some inverse boundary problems for partial differential equations, applications of wavelets in nonparametric estimation;
- algorithmic information theory;
- codes with iterative decoding, code division multiple access (CDMA) systems;
- the development of asymptotic theory nonparametric statistic;
- analysis of systems with complex non-linearities (hysteresis, delays, round-off and discretization effects);
- asynchronous systems;
- hybrid systems;
- oscillation theory, Hopf bifurcations, stability;
- network optimization.

# MAIN RESULTS

The binary nonlinear perfect codes of length 15, Which can be obtained by generalized concatenated construction, were considered and classified. All together there are exactly 777 non-equivalent such codes. In particular, there is one such linear code (the Hamming code) with rank 11. There are 18 such Vasiliev's codes with rank 12, and there are 756 such codes with rank 13.

The large class of q-ary optimal codes is built, which strongly meets this bound.

The coset weight distribution of arbitrary Goethals-like codes are considered. The cosset weight distribution is derived for cossets of weight 1,2,3,5, and 6. The case of cossets of the weight 4 is open. The weight distribution of such cossets is uniquely defined by the number of words of weight 4.

New classes of polynomials over finite fields of odd characteristic are found for which the module of the trigonometric sums has maximal possible value. In particular, some new classes of polynomials are found for which the classical Weyl bound is exact.

The work is concerned with construction of pseudo random sequences by means of Galois rings and cyclic codes over rings. The applications range from cryptography (low autocorrelation binary sequences for streamcipher keys) to communications (PAPR reduction in wireless systems). The techniques employed involve character sums bounds, and Fourier analysis on finite groups.

The study of approximation methods for the construction of attractors of dynamical systems.

Attractors of dynamical systems corresponding to non-autonomous equations of mathematical physics with rapidly oscillating in time exiting forces can have a very complicated structure. So, a new problem was formulated to approximate trajectory lying on such attractors by using the trajectories lying on the attractors of the corresponding averaged equations which, in many cases, can have a simple structure. Besides, there is an important question how to estimate the error of this approximation.

Mentioned above approximations and error estimates were found for the non-autonomous dissipative wave equation, for some non-autonomous reaction-diffusion systems, and for other equations and systems of mathematical physics.

We describe the obtained results for the case of a non-autonomous wave equation with rapidly oscillating exiting forces. We assume that the wave equation with averaged external force has a finite number of stationary points and all of them are hyperbolic. In this case, the attractor of the averaged equation has a simple structure: it is the union of unstable manifolds issuing from the stationary points. We have proved the following result: any piece of trajectory lying on the attractor of the initial equation and having the time length proportional to the logarithm of the oscillating frequency of the exiting force can be approximated by using a finite number of pieces of trajectories lying on the unstable manifolds of the averaged equation. We have also found the explicit formula for the error estimate of this approximation. We have proved that this error estimate is proportional to a certain power of the inverse value of the oscillating frequency of the external force of the original equation.

The similar results concerning the approximations and error estimates are proved for some classes of non-autonomous systems of reaction-diffusion equations and for other equations of mathematical physics.

We have obtained analogous results in the cases when the amplitude of oscillation of the exiting force is growing together with oscillating frequency.

Necessary and sufficient conditions for the linear detector to be asymptotically optimal are given. In particular, it is shown that finding the asymptotically best linear detec-

tor and the largest asymptotic efficiency represents a standard problem of convex analysis in Euclidean space – finding the distance from a point to a convex set.

An effect of a very slow convergence rate in parameter estimation problems was discovered and investigated (when Fisher information matrix degenerates).

The most efficient practical algorithms of data compression were analyzed. It was found out that the algorithm PPM and all it's modifications are very efficient ones due to the (indirectly proposed) specific property of the real data. This property is the "closeness" of conditional probability distributions, corresponding to "close" contexts. Thus for increasing the efficiency of the compression algorithms it is necessary to use this property. First of all several definitions of the term "coding divergence" (which is inverse to the term "closeness") were proposed and compared. Then the universal source coding method for all Markov chains with upperbounded coding divergence was developed and analyzed.

The relation between methods of group invariance of graphs and stability of graphs against failures of vertex.

The idea about the bi-bilinear form is introduced. Due to this idea the relation between of properties of Boolean functions which is further away from any linear function and sums of quadruple arbitrary vectors of shortened Kerdock code is established. This result permit to mace more precise the parameters of some separating systems.

Theory of turbo codes and low-density parity-check codes. New construction of turbo codes using as component codes superorthogonal convolutional codes is suggested and investigated. These codes are very perspective for using in cellular telephone networks of the third generation. Exact analytical expressions for the bit error probability of memory 2 convolutional code are derived. The results can be used for analysis of turbo codes.

The purpose of researches was the investigation of the goodness-of-fit test properties designed for verification of the concordance between the theoretical statistical model and the experimental data. It was considered the Kramér-von Mises statistic based on the components of the empirical process. The power of the similar statistics can be changed in the large limits for the concrete alternatives. It was considered also the power of the goodness-of-fit tests based on the spacings. These tests belong to the class of the tests using the nonparametric density function estimators. It was stated that such type of the tests can have the best power then the tests based on the empirical processes. The goodness-of-fit methods was been applied to developing of the tests for the Pareto distribution tails and for the Rash model using in the quality life analysis.

Properties of discontinuous orientation preserving degree-one mappings of the circle were investigated. The notion of the rotation number of the circle map was extended to such mappings. It was shown that for such mappings the rotation number continuously depends on the graph of the mapping in the Hausdorff metric. New proofs of undefinability in o-minimal structures of the problem on existence of a common nontrivial invariant set for a family of matrices were proposed.

The research of mathematical hysteresis and related topics was continued. In particular, a series of new theorems for polyhedral sweeping processes with oblique reflection was proved together with P. Krejci. Special attention was paid to the averaging methods for differential equations with hysteresis.

One of the most important areas of application of multidimensional hysteresis operators such as polyhedral sweeping processes with oblique reflection is the theory

of queuing networks. New criteria of stability and unique solvability of fluid models of queuing networks with a finite-dimensional state space were found.

The mean field model of a single-class queuing network under the FIFO discipline was studied. Ergodicity of the process was proved in essentially less restrictive situations than before. In parallel, a new theorem on the smoothing properties of a single server under a Poisson inflow of variable intensity was proved: the maximal integral intensity of the outflow during a time window of given length does not exceed the same characteristic of the inflow.

The basic fractional analogue of the classical linear-quadratic Gaussian regulator problem in continuous-time has been solved. For a completely observable controlled linear system driven by a fractional Brownian motion, we describe explicitly the optimal control policy which minimizes a quadratic performance criterion.

The filtering problem is revisited in the basic Gaussian homogeneous linear system driven by fractional Brownian motions. We exhibit a simple approximate filter which is asymptotically optimal in the sense that, when the observation time tends to infinity, the variance of the corresponding filtering error converges to the same limit as for the exact optimal filter.

A homotopy method is proposed for computing the maximum likelihood parameter estimators in dynamic regression models with non-Gaussian innovations of Kotz type.

A generalized method of moments is applied to estimating the unknown parameters of discretely sampled conditionally Gaussian Markov jump-diffusion processes.

A method is developed for identification of a semi-physical model for meteorological processes of autoregressive type with exogenuous input, with the role of the latter played by the solar energy rate as a function of time and latitude.

The phenomenon of delayed loss of stability by dynamic bifurcations in singularly perturbed systems was studied. We obtained simple formulas that determine such a delay in degenerate situations where characteristics of nonlinear terms play the main role.

In 2003 we studied problems on asymptotic bifurcation points for equations with a parameter in the case where an eigenvalue of the principle linear part is of multiplicity 2. We described a class of problems where the number of unbounded branches of solutions may be arbitrarily large. For all problems of this class the main terms of one of the bifurcation system equations degenerate. We suggested a new method to calculate the next order terms. The method allows to estimate the number of unbounded branches of solutions in a vicinity of the asymptotic bifurcation point. The method is applicable to problems on forced periodic oscillations, subharmonics and some other boundary value problems. For problems on unbounded branches of subharmonics the degenerate situation considered is generic.

Generically, for example for bifurcations generated by a simple eigenvalues of linear operators, exactly two unbounded branches exist. In the problem on forced periodic oscillations we find a class of systems such that as minimum six unbounded branches exist.

We investigate the existence of sequences of subharmonics for nonresonant pendulum-like equations with unbounded periods and amplitudes. The unexpected role is played by continued fractions and some other questions of approximation theory.

In the framework of research projects aimed at investigation of oscillations in systems with hysteresis, we studied models of plastic hysteresis described by closed systems of operator-differential equations with the terms like the derivative of the play output. Sufficient conditions for existence of a globally stable forced periodic regime were suggested for the Armstrong–Frederick and Armstrong models.

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A comparative study of a class of recognition methods for "events" that correspond to certain types of contractions in pregnant women electromyograms A package of Matlab subroutines is developed. The results served as base for the project "Development of information system to support researches in the field of premature birth on the basis of complex analysis of electrophysiological and clinical data".

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- **Russian Foundation of Basic Research (No. 03-01-00258):** "Methods to analyze processes in aggregated nonlinear control systems and data transmission systems with hysteresis and other nonsmooth nonlinearities and with weak organization of internal interaction".
- **Russian Foundation of Basic Research (No. 01-01-00146):** "Periodic oscillations in control systems".
- **Russian Foundation of Basic Research (№ 02-01-00227):** "Global attractors for systems of equations of mathematical physics, theory of perturbation and averaging".
- **Russian Foundation of Basic Research (No. 03-01-00592):** "Investigation of probabilistic and combinatorial features of data transmission, storage and processing systems".
- **Russian Foundation of Basic Research (No. 03-01-00098):** " Errorstability in modern communication systems ".
- **Australian Research Council and Tarong Energy, Ltd., Linkage Grant C0010 6980:** "Modeling and risk analysis in Australian energy markets".

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Articles


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Submitted

1. Стенина И.И., Шевердяев А.Ю. Сравнительное исследование методов распознавания "событий" в нестационарных временных рядах, порожденных одним классом электрофизиологических сигналов.
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7. Vladimirov I., Thompson H.B. Homotopical parameter estimation in dynamic regression models with Kotz type noise.
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Abstracts

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