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Seventieth Birthday Anniversary of Academician Nikolai A. Izobov

On January 22, 2010 Nikolaĭ Alekseyevich Izobov, member of Editorial Board of our journal, a well-known mathematician, Academician of the National Academy of Sciences of Byelorussia, Professor, Doctor of Physics and Mathematics, Winner of the State Prize of Republic of Byelorussia, became 70 years of age.

N. A. Izobov was born in Krasyni village of Lioznensk district, Vitebsk oblast of Byelorussia. In 1958 he left the Yanovichi secondary school with gold medal and in 1965 he graduated from the Faculty of Mathematics of the Byelorussian State University, majoring in differential equations. Still a student, N. A. Izobov was awarded the medal “For the Best Scientific Student Work” at the All-Union Competition of Student Works for the results obtained in a course of investigations of the structure of sets of Perron’s lower exponents of linear differential systems.

In 1966, N. A. Izobov continued his post-graduate studies (under supervision of Professor Yu. S. Bogdanov) and in 1967 he defended his Candidate’s

Thesis. Since 1969, during 22 years he was Deputy Editor-in-Chief of the All-Union Journal "Differential Equations", of which the first 12 years he was the staff deputy, remaining a member of the Editorial Board of the journal for all subsequent years. After having defended in 1979 his Doctor's Thesis and being elected in 1980 Corresponding Member of the Academy of Sciences of Byelorussian SSR, he been working at the Mathematical Institute of National Academy of Sciences of Byelorussia successively as a senior researcher (1980–1986), Head of the Laboratory of Stability Theory (1986-1993) and Head of the Department of Differential Equations (from 1993 up to now). In 1994 we was elected Academician of the Academy of Sciences of Byelorussia. In 1996–1999, N. A. Izobov headed the Chair of Higher Mathematics of the Byelorussian State University.

The main areas of N. A. Izobov's scientific investigations are the theory of Lyapunov's characteristic exponents, the theory of stability according to a linear approximation, linear Coppel–Conti systems, Emden–Fowler equations and Linear Pfaff systems.

The Theory of Lyapunov's Characteristic Exponents. In his first works [1,2, see also 61] included in the Candidate's Thesis [6], N. A. Izobov has established that almost all solutions of an n-dimensional ordinary linear differential system with bounded piecewise continuous coefficients, starting at a k-dimensional ($k = 1, \dots, n$) hyperplane of the space R^n, have the lower Perron's exponent equal to the maximal one of the lower exponents of those solutions. He also proved that there exist linear systems whose set of lower Perron's exponents has the power of the continuum [2] and of positive Lebesgue measure. Thus he has established principal distinctions between the structure of the sets of Lyapunov's characteristic exponents and Perron's lower exponents. Later on, these systems were used by E. A. Barabanov for a complete description of sets of lower exponents. Recently, N. A. Izobov [140, 142], jointly with A. B. Filiptsov, proved that, in particular, the maximal Perron's lower exponent of a linear differential system coincides with the Perron's lower exponent of its fundamental system of solutions.

Concerning the freezing method which traces back to P. Bohl, N. A. Izobov proved [18] that in the two-dimensional case his basic estimate – the Alekseyev–Vinograd estimate of the highest characteristic exponent of linear non-stationary system is attainable (in the n-dimensional case this fact was established later by Yu. I. Elefteriadi). N. A. Izobov also obtained more precise versions of that estimate as well as its integral version for two-dimensional [16–19] and n-dimensional [22, 43] linear differential systems. The freezing method closely relates to the construction [22] of a normal system of solutions of the n-dimensional linear differential system with the coefficient matrix which has the maximal norm $\delta > 0$ of its derivative on the positive semi-axis and whose eigen-values $\lambda_k(t)$ are real and separated from each other by a constant $\Delta > 0$. For the constructed normal system of solutions, in the domain $\Delta \geq \delta^{1/(2n-1)}$ there were obtained non-improvable estimates of the angle deviations between the corresponding solutions and eigen-vectors of the coefficient matrix (by the constant $const \times \delta\Delta^{2/(1-n)}$), as well as the estimates (by the function $\exp 2\delta\Delta^{2/(1-n)}t$) of the ratios of the norms of these solutions and the functions $\exp\int_0^t \lambda_k(\tau)\,d\tau$. To the freezing method relates also the proof [20] of reducibility (by means of a Lyapunov transformation) of a general two-dimensional linear system to an almost diagonal one whose out-of-diagonal elements do not exceed by absolute value the exact constant $const \times \delta^{1/(1+n)}$.

Concerning the problem on stability of Lyapunov's characteristic exponents of a linear differential system with respect to small perturbations which traces back to Perron, jointly with B. F. Bylov and independently of V. M. Millionshchikov (but applying his method of rotations), N. A. Izobov obtained [11, 12] a criterion of their stability (the sufficiency of that criterion had been established earlier in the well-known monograph due to B. F. Bylov, et al. "The Theory of Lyapunov's exponents"). In [21], N. A. Izobov obtained also a coefficient criterion of stability of characteristic exponents for the two-dimensional linear system through eigen-values and eigen-vectors of its coefficient matrix.

In [26, 27, 30, 31, 35, 46], N. A. Izobov introduced a notion of the minimal exponent of a linear system as the exact lower bound of the highest exponents of linear systems with small perturbations and proposed an algorithm for its calculation in the two-dimensional case, while in the n-dimensional case he obtained the lower bound. N. A. Izobov derived [37] calculation formulas for the determined by him in [37, 39,40, 42] the highest and the lowest exponential exponents of the linear system by means of its Cauchy matrix and time geometrical sequences. These exponents are used [40, 42] in solving Lyapunov's special problem on exponential stability according to a linear approximation. N. A. Izobov proved [159, 160] simultaneous instability of lowest and highest exponential exponents of linear differential systems in the following classes of linear perturbations: (1) with characteristic powers equal to $-\infty$; (2) summable on the positive semi-axis with arbitrary power weight. N. A. Izobov introduced [10; see also 57] a notion of highest sigma-exponent of the general linear system as an exact upper bound of highest exponents of linear systems with perturbations exponentially decreasing with velocity $e^{-\sigma t}$, $\sigma > 0$, and, using the Cauchy matrix, he suggested an algorithm of its calculation; later, in [41], jointly with E. Barabanov, he completely described the properties of the abovementioned exponent. The exponential and the sigma-exponents are now called Izobov's exponents. For the set of two-dimensional linear differential systems, N. A. Izobov [79, 80, 83, 90, 119] presented a complete description of mutual disposition of Lyapunov's characteristic exponents, as well as exponential, Vinograd's central and general Bohl exponents.

Starting from his first work [3], N. A. Izobov devoted much attention to the investigation of linear systems with exponentially decreasing perturbations. In particular, in collaboration with O. P. Stepanovich [69, 71, 73, 75], he singled out a class of perturbations and established the existence of linear systems whose characteristic exponents coincide or, respectively, do not coincide with characteristic exponents of linear systems with generalized Grobman perturbations. Moreover, in [76-78, 81], N. A. Izobov proved the stability of highest upward and lowest downward characteristic exponents of linear systems with respect to the same perturbations and established that there exist Grobman spectral sets of positive Lebesgue measure. Jointly with S. G. Krasovskiĭ [126, 130] he gave the description of a method of constructing two-dimensional linear systems with parameter at the derivative and with unbounded with respect to that parameter Lebesgue measure of the spectral sigma-set of characteristic exponents. In [81, 84 and 85], N. A. Izobov obtained attainable deviation estimates of the characteristic exponents of the same type of the initial and the perturbed system with exponentially decreasing perturbations, and in [146, 149, 150], using characteristic exponents of the initial system, he obtained lower bounds of characteristic exponents for linear systems with Perron perturbations. In collaboration with S. N. Batan, he established [147, 148] analogous estimates in the case of the so-called generalized Perron perturbations.

N. A. Izobov gave also a complete description [168, 171] of the relative position on the positive semi-axis of: the coincidence boundary of highest sigma- and characteristic exponents of the linear differential system; its Grobman irregularity coefficient; and the values of the norm of the coefficient matrix. One should also mention the works [5, 6] and those carried out jointly with A. V. Filiptsov [92, 94, 97, 103, 110] dealing with the investigation of invariance of lowest Perron's exponents of solutions of linear systems with respect to exponentially decreasing perturbations, as well as the works [140, 142], where the maximal lower Perron's exponent of the linear system is calculated by means of its fundamental system of solutions.

In a series of works [169, 170, 173, 177, 180, 191] carried out in collaboration with S. A. Mazanik and devoted to systems reducible in Lyapunov's sense: (1) integral criteria of reducibility of a perturbed linear differential system to the initial one are proved and it is established that they are nonimprovable; (2) the notions of the reducibility coefficient and the reducibility exponent of the linear system are introduced, their interconnection is investigated and their attainable boundaries are found that are expressed through the difference of highest and lowest general, central, or exponential indices as well as through the value of norm of the coefficient matrix of that system; (3) the properties of the introduced sets of reducibility and irreducibility of linear systems are thoroughly investigated.

Here it is also worth mentioning the joint with E. K. Makarov solution [60, 68] of Yu. Bogdanov's problem on existence of a regular linear system becoming irregular when its coefficient matrix is multiplied by a positive scalar parameter. Linear periodic systems are treated in N. A. Izobov's works [24, 25, 28 and 29].

The monograph [179] is devoted to a brief and very incomplete exposition of the above-mentioned results of N. A. Izobov as well as of those given in the section below. In that monograph, just as in many of his works, N. A. Izobov systematically applies V. M. Millionshchikov's method of rotations.

Stability According to a Linear Approximation. To investigate exponential stability according to a linear approximation of a differential system with perturbations of order $m > 1$, N. A. Izobov introduced [9; see also 15] a priori m-exponents $\Omega_m(A)$ and constructive m-exponents $\Omega''_m(A)$ (the latter computable by means of the Cauchy matrix) of the linear system $\dot{x} = A(t)x$, $x \in R^n$, $t \geq 0$, whose negative values, as functions of the parameter m, he completely described [49, 50, 63, 91] by means of uniformly convergent series. We also mention here N. A. Izobov's results [56, 59] concerning the existence of differential systems with exponentially stable linear approximations and perturbations of higher order of smallness, whose set of characteristic and lower exponents are of positive Lebesgue measure. Another properties of these sets have been established by N. A. Izobov in collaboration with I. A. Volkov [64, 65, 67].

As is known (see, e.g., 145, 157, 179, p. 262), there exist the special and the general Lyapunov's problems on the exponential stability according to a linear approximation of the differential system with perturbations, respectively, of unfixed higher order of smallness and of fixed order $m > 1$.

The solution of the special problem was obtained by N. A. Izobov [40, 42 and 138]: the zero solution of the differential system is exponentially stable with respect to any perturbation of higher order of smallness if and only if the constructive exponent $\Omega''_m(A)$ of the linear approximation system is negative for every $m > 1$. In the case of the stronger property of exponential stability, this criterion consists [39, 40, 42, 138] in the negativeness of the exponential exponent of the linear approximation system which provides general attainable exponential asymptotics of solutions.

When solving the general Lyapunov's problem, N. A. Izobov, jointly with R. E. Vinograd [13–15], established that R.E. Vinograd's condition $\Omega'_m(A) < 0$ for the estimating exponent $\Omega'_m(A)$ of the linear approximation system is sufficient, while N. A. Izobov's condition $\Omega''_m(A) < 0$ is necessary (see also [9]) for the exponential stability of the differential system with the linear approximation $\dot{x} = A(t)x$, $x \in R^n$, $t \geq 0$, and any perturbation of order $m > 1$. This fact in the noncritical case when the above-mentioned exponents coincide provides a solution of the general problem. However, in the critical case, as established by N. A. Izobov [52; see also 93] later, these conditions are not, respectively, necessary and sufficient for the exponential stability. Moreover, N. A. Izobov [52] obtained a complete solution of the above-mentioned problem in the case of the linear diagonal approximation. A presentation of the above-obtained results can be found in the review papers [145, 157].

Linear Coppel-Conti's Systems. N. A. Izobov, in collaboration with R. A. Prokhorova, carried out a complete enough investigation [66, 62, 63, 66, 72, 74, 82, 85, 95, 192, 197, 117, 118, 139] of the structure of the

Coppel–Conti sets L^pS and N^pS, $p \geq 1$, of, respectively, asymptotically stable and unstable linear systems with unbounded, in general, coefficients. These systems determine the boundedness of all or of only one solution of inhomogeneous linear systems with corresponding non-homogeneities.

In particular, they solved the first Conti problem on narrowing of the sets L^pS and N^pS, as $p > 0$ increases, and establised that there exists no continuous from the left dependence of these sets on the parameter p. In [72, 74], criteria are obtained for the coincidence of the sets L^pS and N^pS with their interior, as well as the second Conti problem is solved on the coincidence of the set $\lim\limits_{p\to+\infty} L^pS$ with its interior, as a special case of a more general problem. N. A. Izobov [86, 97], jointly with R. Conti and R. A. Prokhorova, studied thoroughly the preblem on the simultaneous belonging of the initial and perturbed linear systems with summable on $[0, +\infty]$ perturbations to the sets L^pS, as well as to their left and right limiting, at the point $p = q$, sets.

During the last decade, N. A. Izobov, in collaboration with R. A. Prokhorova, completely described [158, 161, 163] the set of all such asymptotically stable linear differential Coppel–Conti systems and established that the zero solution of every nonlinear system with linear approximation from that set and any perturbation of higher order of smallness is asymptotically stable. They also described [164–166] the set of all unstable linear differential Coppel–Conti systems for which every nontrivial solution of an analogous nonlinear perturbed system, starting from a sufficiently small neighborhood of the origin of coordinates, in a finite time gets to the boundary of that neighborhood. The same authors proved [174, 178, 201] that the highest characteristic exponent and the lowest characteristic exponent of, respectively, asymptotically stable and unstable linear Coppel–Conti systems are, respectively, negative and positive, and obtained their upper and lower bounds. They also proved [163, 182, 201] that the Lyapunov's characteristic exponents are negative for all starting in a sufficiently small neighborhood of the origin solutions of a nonlinear differential system with perturbations of higher order of smallness and with linear asymptotically stable Coppel–Conti approximation. Using a constant defined by means of the linear Coppel–Conti approximation, the upper bound for exponents of these solutions is obtained [163, 182, 201]. Thus a complete solution is presented for Lyapunov's problem on the exponential stability according to the above-considered linear Coppel–Conti approximation.

N. A. Izobov established [186, 192] conditional exponential stability of the zero solution of a multi-dimensional nonlinear differential system with a general integro-dichotomous linear Coppel–Conti approximation and a nonlinear perturbation of higher order of smallness which is piecewise continuous in the time variable and continuous in the phase variables in some neighborhood of the origin of coordinates. The existence of a k-dimensional family of exponentially decreasing (as the time increases) solutions of the above-mentioned nonlinear system is proved, and an upper estimate of characteristic exponents of those solutions is obtained.

The monograph [190] by N. A. Izobov and R. Prokhorova is devoted to the exposition of their results of investigation of properties and structure of a dependent on a parameter set of linear differential Coppel–Conti systems and its main subsets.

The Emden–Fowler Equations. Investigations by N. A. Izobov of the classical equation $u^{(n)} = p(t)|u|^{\lambda}\operatorname{sign} u$, $n \geq 2$, $\lambda > 0$, $t \geq 0$, with a function $p(t)$ of constant sign are initiated by and connected with solving [44, 45, 48] of two I. T. Kiguradze's problems on necessity of well-known existence criteria for the Emden-Fowler equation to have:1) in case $\lambda > 1$, an n-parametric family of infinitely right-extendable monotone solutions; 2) in case $p(t)$ satisfies $(-1)^n p(t) \geq 0$ for $t \geq 0$ and $\lambda \in (0, 1)$, vanishing at infinity regular Kneser solutions.

In [44,45], N. A. Izobov obtained a general integral criterion (involving a fractional parametric power of the function $p(t) \geq 0$) for the above equation with $\lambda > 1$ not to have unbounded regular solutions and established that this criterion is non-improvable. Moreover, in [44], for the Emden–Fowler equation of second order he obtained criteria for existence and nonexistence of unbounded regular solutions with an additional differential property. Jointly with V. A. Rabtsevich, N. A. Izobov [54, 58] established that the Kiguradze–Kvinikadze's criterion on existence of regular solutions of the Emden–Fowler equation with $\lambda > 1$ is non-improvable.

In [48], N. A. Izobov obtained a parametric integral criterion of nonexistence of Kneser solutions of the Emden–Fowler equation with $\lambda \in (0, 1)$, and proved its exactness for the case $n = 2$. Jointly with V. A. Rabtsevich [70] he made somewhat more precise this criterion for $n \geq 3$ and established that it is non-unimprovable.

Linear Pfaff's Systems. In [113, 114, 120, 122, 123, 125, 129, 131, 136], N. A. Izobov, in particular, established that there exist linear completely integrable Pfaff's systems with two-dimensional time, the countable number of different characteristic sets of solutions and with the lower characteristic set (introduced in [114] as an analogue of the set of lower Perron's exponents in the case of one-dimensional time) of positive plane Lebesgue measure. Moreover, N. A. Izobov, in collaboration with A. S. Platonov, [121, 124, 128, 133, 135, 137, 143], established other properties of lower characteristic sets, having proved, in particular, that almost all solutions of the linear Pfaff's system with two-dimensional time starting at an arbitrary k-dimensional subspace of the n-dimensional space, have lower characteristic sets coinciding with the least upper bound of the whole set of lower characteristic vectors of these solutions. Besides, N. A. Izobov jointly with S. G. Krasovskiĭ and A. S. Platonov, proved [193, 197, 198] that there exist n-dimensional completely integrable linear Pfaff's systems with k-dimensional time and the lower characteristic set of positive Lebesgue measure in the k-dimensional space.

In collaboration with E. N. Krupchik, N. A. Izobov completely described [141, 144, 151, 153] the structure of limiting lower power characteristic sets of nontrivial solutions of linear fully integrable Pfaff's systems with two-dimensional time. They also gave [154] a complete description of the limiting left and right lower and upper power sets of nontrivial solutions of such systems. They constructed [162, 167] a completely integrable linear Pfaff's system with arbitrarily prescribed piecewise continuous characteristic power functions (having, in particular, a countable number of points of discontinuity) of its nontrivial solutions.

Of special interest is the following special result obtained by N. A. Izobov [181]: any two-dimensional linear Pffaff's system with two-dimensional time has at most countable number of solutions with different characteristic sets. As it was pointed out, earlier N. A. Izobov established [122] that linear Pfaff's systems with the countable number of such solutions do exist.

Along with intensive enough theoretical investigations in the asymptotic theory of differential systems, N. A. Izobov carried out a series of investigations of applied character, for example, in the mechanics of motion of objects along surfaces close to spherical ones (see [175, 178, 183, 185, 188, 189, 194-196, 199, 200]).

N. A. Izobov has published more than 200 scientific works. Under N. A. Izobov's supervision over 21 Candidates and Doctors of Sciences defended their theses. He has been Chairman of the Expert Council in Mathematics of the Higher Certifying Commission of Republic of Byelorussia (and is its member at present), a member of Bureau of Physics, Mathematics and Informatics Department of National Academy of Sciences of Byelorussia, a member of Editorial Board of "Central European Journal of Mathematics". At present he is member of editorial boards of the journals "Differentsial'nye Uravneniya", "Memoirs on Differential Equations and Mathematical Physics", "Doklady NAN Belarusi", "Vestsi NAN Belarusi. Ser. Fiz.-Mat. Navuk", Deputy Editor-in-Chief of the journal "Trudy Instituta Matematiki NAN Belarusi".

N. A. Izobov was decorated with Frantsisk Skorina Order and awarded the State Prize of Republic of Byelorussia.

Editorial Board wishes Nikolaĭ Alekseyevich Izobov good health and new successes.

R. P. Agarwal, I. Kiguradze, T. Kiguradze,
S. G. Krasovskii, T. Kusano, G. Kvinikadze,
A. Lomtatidze, V. P. Maksimov, F. Neuman,
N. Partsvania, M. O. Perestyuk,
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