MATHEMATISCHES FORSCHUNGSINSTITUT OBERWOLFACH

T a g u n g s b e r i c h t 34/1983

Functional Analysis and Approximation

30.7 bis 6.8.1983

Die Tagung stand diesmal unter der Leitung von P.L. Butzer, R.L. Stens (beide Aachen) und B. Szökefalvi-Nagy (Szeged). Es nahmen insgesamt 61 Mathematiker aus 15 Nationen teil, von denen viele zum erstenmal überhaupt in Oberwolfach waren. Wie schon bei den vorausgegangenen Tagungen dieser Reihe hatten die Veranstalter besonderen Wert darauf gelegt, nicht nur bekannte Namen aus den verschiedenen Fachgebieten, sondern auch eine große Auswahl junger Wissenschaftler einzuladen. Das Oberwolfacher Institut bietet nämlich durch seine persönliche Atmosphäre die einmalige Gelegenheit zu Gesprächen und Diskussionen zwischen Jung und Alt, wie es an anderen (größeren) Tagungsorten nur selten möglich ist.

Das umfangreiche wissenschaftliche Programm (49 Vorträge) konnte nur dadurch bewältigt werden, daß man traditionsgemäß schon Sonntag morgens begann und erst am späten Freitagabend endete. Umso erstaunlicher war es, daß das Interesse selbst bei den letzten Vorträgen noch außergewöhnlich hoch war. Es wurde ein breites Spektrum von Themen aus den verschiedensten Gebieten der Approximationstheorie, der Funktionalanalysis, der Operatortheorie und der Fourieranalysis behandelt. Das offizielle Programm wurde abgerundet durch zwei Sitzungen, in denen neue und ungelöste Probleme vorgestellt wurden.

Neben den mathematischen Vorträgen wurden in einer Feierstunde, an der auch Professor M. Barner teilnahm, über das Leben der Professoren

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L. Illiev, R.S. Phillips, B. Szökefalvi-Nagy und A.C. Zaanen berichtet, die an vielen der bisherigen Tagungen dieser Reihe teilgenommen haben und in diesem Jahr ihr 70. Lebensjahr vollendeten.

Wie schon anläßlich der früheren Tagungen werden Ausarbeitungen der Vorträge im Birkhäuser Verlag, Basel, in der Reihe ISNM, diesmal als Bd. 65, erscheinen.

Zum Schluß ein Wort des Dankes an das gastgebende Institut. Die hervorragende Betreuung durch das gesamte Personal trug wesentlich zum Gelingen der Tagung bei.

Vortragsauszüge

C. BENNETT:

Nontangential maximal functions and bounded mean oscillation

Characterizations are obtained of the functions of bounded lower oscillation (BLO) in terms of the nontangential maximal functions of functions of bounded mean oscillation (BMO). As a corollary, one obtains a characterization of the harmonic functions in $\mathbb{R}^{+}_{n+1}$ whose traces belong to $BLO(\mathbb{R}^n)$.

H. BERENS:

On maximal extensions of accretive operators in the plane

In 1962 Minty proved that for a real Hilbert space H a monotone (accretive) operator $A \subset H \times H$ is maximally monotone exactly when there exists $\lambda \in \mathbb{R}^{+}$ such that (and consequently for all $\lambda \in \mathbb{R}^{+}$) $I + \lambda A$ is a surjection of A onto H. In the Banach space setting the latter property is called m-accretiveness. In contrast to Minty's result Crandall and Liggett showed in 1971 that for $l_p(\mathbb{Z}), 1 \leq p \leq \infty$, the class of m-accretive operators coindes with the class of maximally accretive ones exactly when $p = 1, 2,$ or ∞. In joint work with Dr. Hetzelt we extended Crandall's and Liggett's result as follows: Let X be a real, 2-dimensional, normed vector space with a strictly convex and smooth norm. If every accretive operator in $X \times X$ has a m-accretive extension, then the norm generates an inner-product.

W. C. CONNETT:

Convolution structures for eigenfunction expansions arising from regular Sturm - Liouville problems

The eigenfunctions associated with a regular Sturm - Liouville problem behave "like" trigonometric expansions in many ways - for example there are various asymptotic estimates and equi-convergence theorems. In order to utilize the full machinery of harmonic analysis, however, it is necessary to have some substitute for the group structure so useful in arguments concerning trigonometric expansions. That substitute is a positive convolution which is shown to exist, and then utilized to prove various maximal function inequalities.

R. DEVORE:

Differentiation in $\mathbb{R}^n$

Recently, E. M. Stein (Ann. of Math. 1981) proved the following generalization of Lebesgue's theorem $(n=1)$:

Theorem. If the weak gradient ∇f is locally in the Lorentz space $L_{n,1}(\mathbb{R}^n)$, then f can be redefined on a set of measure zero so as to be continuous and $|f(x+h) - f(x) - \nabla f(x)\cdot h| = o(|h|)$, $h \to 0$, a.e.x.

Stein's proof of this theorem relies heavily on techniques of harmonic analysis - Riesz potentials and singular integrals. With R. Sharply, we present a simple proof of this theorem based along the lines of Lebesgue's theorem. Namely, we show that $\lim_{Q\downarrow\{x\}} f_Q =: F(x)$ defines a continuous function F where the Q are cubes in $\mathbb{R}^n$ and $f_Q := (1/|Q|)\int_Q f$. In addition,

$$(*) \qquad |f(x+h) - f(x) - \nabla f(x)\cdot h|/|h| \leq c\, M_n(\nabla f)(x)$$

where $M_n g(x) := \sup_{x \in Q} \|\chi_Q g\|_{L_{n,1}} / \|\chi_Q\|_{L_{n,1}}$. The classical differentiation of f now follows from (*) and the fact that M_n is of weak type (n,n).

W. DICKMEIS:

On condensation of singularities on a set of full measure

Continuing previous investigations on quantitative uniform boundedness and condensation principles with R. J. Nessel, another version of a condensation principle is given. Concerning the Bernstein polynomial $B_n(f;x) = \sum_{k=0}^{n} \binom{n}{k} x^k (1-x)^{n-k} f(k/n)$, an application delivers: For each $\alpha \in (0,2]$ there exists a function f_α satisfying the usual (generalized) Lipschitz condition of order α such that

$$\limsup_{n\to\infty} \frac{|B_n(f;x) - f(x)|}{[x(1-x)/n]^{\alpha/2}} \geq c > 0$$

for almost every $x \in [0,1]$. This result establishes the sharpness of the rate of convergence $O([x(1-x)/n]^{\alpha/2})$ for the Bernstein polynomials on Lipschitz classes of order α as given by H. Berens and G. G. Lorentz in the sense that there exists (at least) a counterexample f_α for which it cannot be improved to $o([x(1-x)/n]^{\alpha/2})$.

D. GASPAR:

Über die Wold-Zerlegung isometrischer Halbgruppen

Es sei $\{T_s\}_{s \in S}$ eine isometrische Halbgruppe auf einem Hilbert Raum H (S ist eine Untergruppe einer geeigneten Gruppe G). Die Wold-Zerlegung von I. Suciu (1968) besagt, daß $\{T_s\}$ aus einer unitären Halbgruppe $\{T_s^{(u)}\}$, einem Shift $\{T_s^{t}\}$ und dem "evanescenten" Teil $\{T_s^{(e)}\}$ besteht. Unser Anliegen ist es, $\{T_s^{(e)}\}$ weiter zu zerlegen. Dazu benutzen wir einen weiteren Defektraum

$$L := H^{\perp} \ominus P_{H^{\perp}} \bigvee_{g \notin S^{-1}} U_g^{*} H^{\perp}.$$

Dann läßt sich der Hilbert Raum zerlegen in $H = (H^{(u)} \vee H^{(t)}) \oplus H^{ue}$, wo die Restriktionen von $\{T_s\}$ auf diese Unterräume einen modifizierten Shift, einen normalen Shift bzw. eine isometrische "ultraevanescente" Halbgruppe ergeben.

M. VON GOLITSCHEK:

Shortest path algorithms for the approximation by nomographic functions

In a compact domain $D \subset \mathbb{R}^2$ the functions $f \in C(D)$ are approximated in the uniform norm by the class of nomographic functions

$$NOM := \{w \in l_\infty(D) \mid w(s,t) = g(x(s)v(t) + u(s)y(t)),\ (s,t) \in D,\ x \text{ and } y \text{ are arbitrary bounded functions}\}$$

where u and v are given positive continuous functions, g is strictly monotone and continuous. This approximation problem is converted into the negative cycle problem in a properly chosen family of weighted directed graphs, and a version of the Ford-Bellman algorithm for finding the shortest paths leads to constructive proofs of new characterization and existence theorems. Special cases of NOM are well-known approximation subspaces in the theory of integral equations, functional equations, scalings of matrices, Goursat-type problems for the wave equation in $\mathbb{R}^2$, and in bivariate approximation theory.

J. J. GROBLER:

Spectral properties of positive operators

In answer to a problem posed by A. C. Zaanen we prove the spectral radius theorem of Ando-Krieger without using any representation methods. The theorem states that a positive and band irreducible abstract kernel operator on a Dedekind complete Banach lattice has a strictly positive spectral radius. As a result the abstract version of the theorem of Jentzsch can be derived without resorting to representation theory. The key to our proof is a new proof of Schaefer's theorem: An irreducible operator on a Banach lattice, which is a closed ideal in a Dedekind complete AM-space with unit, has a positive spectral radius.

K. GUSTAFSON :

Graph theory in the approximation theory of fluid dynamics

We consider a viscous incompressible liquid whose flow in a vessel Ω in Euclidean space is governed by the Navier-Stokes equations. In a number of finite element schemes satisfying the incompressibility condition, a difficulty has been the lack of explicit bases, and in some cases, even their dimension has been unknown. We employ graph theory to calculate the dimensions of these approximating incompressible subspaces and to obtain bases for them.

References: [1] R. Temam, Navier-Stokes Equations, Theory and Numerical Analysis, Elsevier-North-Holland (1979); [2] K. Gustafson and R. Hartman, Divergence-free bases for finite element schemes in hydrodynamics, SIAM J. Numer. Anal. (1983, to appear).

M. DE GUZMÁN:

New methods for maximal convolution operators

Let $\{k_j\}_1^\infty \subset L^1(\mathbb{R}^n)$ be a sequence of kernels. Define the operators K_j acting on $L^1(\mathbb{R}^n)$ by setting $K_j f = k_j * f$. Let $K^*f(x) = \sup_j |K_j f(x)|$. In order to prove the a.e. convergence of $K_j f$ one is led to proving the weak type (1,1) for the maximal operator K^*, i.e., $|\{x \in \mathbb{R}^n : K^*f(x) > \lambda > 0\}| \leq c\,\|f\|_1/\lambda$, c independent of λ, f. One useful theorem to do this in an effective way is the following: K^* is of weak type (1,1) exactly when K^* is of weak type (1,1) over finite sums of Dirac deltas, i.e., when

$$|\{x \in \mathbb{R}^n : \sup_j |\sum_{k=1}^{H} k_j * f(x)| > \lambda\}| \leq cH/\lambda .$$

Several recent instances of the use of this theorem by Krogstadt, Carlsson, Guzmán,... are given that show the power of the theorem to simplify and clarify some important theorems and to obtain new results.

P. R. HALMOS:

Subnormal suboperators and the subdiscrete topology

A suboperator is a bounded linear transformation from a subspace H_o of a Hilbert space H into all of H; it is subnormal if it can be extended to a normal operator on H. Principal problem: characterize subnormal suboperators. Subquestion: what is the closure (e. g., strong topology) of the set of all suboperators from H_o (fixed) into H? The paper solves some related problems (but not the ones stated here - they are unsolved). Pertinent concept: the subdiscrete topology of operators on H is the specialization to $B(H)$ of the Tychonoff product topology of H^H, where the exponent is given the discrete topology. This circle of ideas has close connection with Bishop's theorem to the effect that the strong closure of the normal operators is the set of subnormal operators.

P. R. HALMOS:

Béla Szökefalvi - Nagy

A report on the life of Professor Béla Szökefalvi - Nagy, born on July 29, 1913, in Koloszavár (now Cluj), Professor of Mathematics at the University of Szeged.

W. K. HAYMAN:

The best harmonic approximant to a continuous function

Suppose that f is bounded and continuous in a domain D in $\mathbb{R}^k$. Then there exists a best harmonic approximant to f in the uniform norm. If D is a Jordan domain, f is continuous in $\bar{D}$ and h be a best harmonic approximant to f which has a continuous extension to $\bar{D}$, then h is unique and can be characterized in terms of the sets in $\bar{D}$ where $h-f$ assumes the extreme values $\mp m = \sup_{z \in D}|f(z) - h(z)|$. Examples show that if these hypotheses are relaxed in various ways the conclusions may fail. For instance, h need not be continuous in $\bar{D}$ even if f is continuous in $\bar{D}$ and, if f is only bounded and continuous in D, h need not be unique. Further, the characterization can break down if D is the unit disk cut along the non-positive real axis. The work is joint with D. Kershaw and T. S. Lyons.

E. HEWITT:

A class of positive trigonometric sums

This is joint work with Prof. G. Brown of the University of New South Wales. Let $(a_k)_{k=0}^{\infty}$ be a nonincreasing sequence of positive real numbers. One seeks reasonable conditions on a_k ensuring that

$$(1)\quad \sum_{k=0}^{N} a_k \cos k\theta \quad \text{and} \quad (2)\quad \sum_{k=0}^{N} a_k \sin k\theta$$

be positive for all $N \in \{1,2,\ldots\}$ and $\theta \in]0,\pi[$. The example $a_0=1$, $a_k=1/k, k\geq 1$, goes back to D. Jackson (1911) for (2) and W. H. Young (1913) for (1). Rogosinski and Szegö dealt with (1) and $a_0=1/2$, $a_k=1/(k+1)$, $k\geq 1$. In 1958, Vietoris proved positivity for (1) and (2) if $a_0=a_1=1$, $a_{2k}=a_{2k+1}=\frac{2k-1}{2k}\, a_{2k-1}$, $k\geq 1$, containing Young's and Jackson's but not Rogosinski's and Szegö's result. We prove positivity of (1) for $a_0=a_1=1$, $a_{2k}=a_{2k+1}=\frac{2k}{2k+1}\, a_{2k-1}$, $k\geq 1$. The proof seems to be involved and requires a new method. The series (2) for our a_k's is positive everywhere in $]0,\pi-\pi/N]$ but not in $]0,\pi[$.

C. B. HUIJSMANS:

Ideals in C(X)

Let C(X) be the Riesz space and algebra of all real continuous functions on some Tychonov space X. The sets of all order, algebra, prime, algebra prime, maximal, and algebra maximal ideals are denoted by $\mathcal{O},\mathcal{A},\mathcal{OP},\mathcal{AP},\mathcal{OM},\mathcal{AM}$, respectively. The following results hold: (1) $\mathcal{OM}\subset\mathcal{AM}\subset\mathcal{AP}\subset\mathcal{OP}$, (2) $\mathcal{O}\subset\mathcal{A} \Leftrightarrow$ X pseudo-compact, (3) $\mathcal{A}\subset\mathcal{O} \Leftrightarrow$ (Gillmann - Henriksen 1956) $C(X)=\{f^+\}^d+\{f^-\}^d\ \forall f\in C(X) \Leftrightarrow$ (Seever 1967) C(X) has the σ-interpolation property, (4) $\mathcal{OM}=\mathcal{AM}\Leftrightarrow$ X pseudo-compact, (5) $\mathcal{AM}=\mathcal{AP}\Leftrightarrow$ C(X) z-regular (Riesz space analogue of von Neumann-regular), (6) $\mathcal{AP}=\mathcal{OP}\Leftrightarrow$ X finite. All these results can be generalized to f - algebras and (in a proper setting) to Riesz spaces. As an example of a general Riesz space theorems Seever's result generalizes to: The Riesz space L has the σ - interpolation property $\Leftrightarrow$ L is normal and relatively uniformly complete. The result that R_π is an order ideal in L for all orthomorphisms π on L whenever L has the σ - interpolation property depends heavily on this theorem.

K. G. IVANOV:

Approximation of functions of two variables by means of algebraic polynomials

Let D be a domain in the plane with the boundary Γ which is a finite union of arcs with continuous curvature so that the angles at the adjoining points are positive and less than π (with respect to the domain). For the best approximation of a function in $L_p(D)$, $1 \leq p \leq \infty$, we state a direct theorem of Steckin's type and a converse theorem of Salem-Steckin's type. In these theorems we use new moduli of continuity for functions of two variables. Some of the properties of these moduli and their connection with the usual ones are given.

J. W. JEROME:

Fixed point and implicit function theorems and their applications

Some of the standard fixed point theorems of analysis, such as the contraction mapping theorem, Tarski's theorem, and the Schauder theorem, and some of the implicit function theorems of analysis will be illustrated via some of the especially useful applications of the last two decades. Applications will include operator equations defined by stable semigroups, quasi-variational inequalities, systems of nonlinear partial differential equations, and local existence theorems.

L. KÉRCHY:

Subspace lattices connected with C_{11}-contractions

We say that a Hilbert space-contraction T belongs to the class C_{11} if for every non-zero vector h the limits $\lim_{n\to\infty} \|T^n h\|$ and $\lim_{n\to\infty} \|T^{*n} h\|$ are not equal to zero. C_{11}-contractions are close to unitary operators in the sense also that they are quasi-similar to unitary ones. We consider the hyperinvariant subspace L of T such that $T \mid L \in C_{11}$. The set of these subspaces is denoted by $\text{Hyplat}_1\, T$. The behaviour of $\text{Hyplat}_1\, T$ under quasi-similarity and its relation to Hyplat T is studied. Among others a negative answer is given to a problem of Sz.-Nagy and Foias.

T. H. KOORNWINDER:

On a new class of generalized functions introduced by J. J. Lodder

In view of applications in quantum electrodynamics J. J. Lodder [1] developed a new class of generalized functions which is closed under multplication, Fourier transform, differentiation, and dilation. However, the proofs in [1] are still somewhat sketchy. In the lecture a more rigorous approach to a big subclass of Lodder's generalized functions will be discussed. It will be obtained as a space of linear functionals on some linear subspace of S'.

[1] J. J. Lodder, A simple model for a symmetrical theory of generalized functions, I-V, Physica 116 A (1982), 45-58, 59-73, 380-391, 392-403, 404-410.

J. KOREVAAR:

$\sqrt{\delta}$

In a recent master's thesis, my student Bitlanzon has shown that there exist integrable functions f on $\mathbb{R}$ such that $f \cdot f = \delta$. There are no real solutions! One can make supp f arbitrarily small. Solutions are constructed "by hand", starting with the periodic case, $\tilde{f} \cdot \tilde{f} = \delta_{2\pi}$. There is a reasonable product definition for $\tilde{f} \cdot \tilde{g}$ via Fourier series: $\tilde{f} \cdot \tilde{g} := \sum_n \{\sum_k \hat{f}(k)\hat{g}(n-k)\}e^{inx}$ when this makes sense. Question: Is there an "analytic" solution f of the equation $f^2 = \delta$, that is, a solution given by an analytic expression?

J. KOREVAAR:

Adriaan Cornelis Zaanen

A report on the life of Professor Adriaan Cornelis Zaanen, born on June 14, 1913, in Rotterdam, Professor of Mathematics at Leiden University since 1956.

L. LEINDLER:

Strong approximation

The aim of the lecture was to present a generalization of Sunouchi's theorem. Our theorem reads as follows: If α, γ and p are positive numbers and $0 < p\gamma < 1$, then $\sum c_n^2 n^{2\gamma} < \infty$ implies

$$\{\frac{1}{A_n^\alpha} \sum_{k=0}^{n} A_{n-k}^{\alpha-1} |s_{\nu_k}(x) - f(x)|^p\}^{1/p} = o_x(n^{-\gamma}), \qquad A_n^\alpha = \binom{n+\alpha}{n},$$

almost everywhere for any increasing sequence $\{\nu_k\}$, where $s_n(x)$ denotes the n-th partial sum of $\sum c_n \varphi_n(x)$, and $\{\varphi_n\}$ is an arbitrary orthonormal system.

G. LUMER:

An exponential representation of Hille - Yosida type for evolution operator

Let X be a Banach space, and B(X) the space of bounded operators on X (all operators here are linear). For $M \in \mathcal{F}_I = \{F : I \to B(X)\}$,

$I \subset \mathbb{R}$ interval, we define $(M\_F)(t) := F(t)M(t)$, $F \in \mathcal{F}_I$, $(DF)(t) := F'(t)$, $F \in \mathcal{F}_I$ differentiable. Consider the Cauchy-problem $(S < s < t < T$, $u \in C([s,T],X))$

(1) $\frac{du}{dt} = A(t)u, \quad u(s) = f \in D(A(s)),$

where $A(t)$ is a dissipative generator such that $t \to R(\lambda, A(t))$ is $B(X)$-continuous $\forall \lambda > 0$. Assume that $\exists\ ]S,T[\ \times X$ dense set of initial values (s_i, f_i) from which start $W^{1,1}([s_i,T],X)$ solutions of (1), $u(t,s_i,f_i) = U(t,s)f_i$, where U is a contractive evolution operator on X. Then U is uniquely determined, and $\forall \lambda > 0\ \exists J_\lambda =]S_\lambda, T_\lambda[\ \uparrow\ ]S,T[$ as $\lambda \to \infty$, and $\exists$ dissipative $A_\lambda(t) \in B(X)$ with $(\mathbb{1}(t) = \text{identity on } X)$

(2) $\begin{cases} A_\lambda(t) \to A(t) \text{ strongly on } D(A)\ \forall t \in J_\lambda \\ U(t,s) = \lim\limits_{n\to\infty} (e^{(t-s)(A_\lambda - + D)}\mathbb{1})(s) \text{ strongly on } X. \end{cases}$

For $A(t) = A$ being constant this result subsumes the usual Yosida and Hille-Yosida representation formulas.

C. MARKETT:

Product formulas for Bessel, Whittaker, and Jacobi functions via the solution of an associated Cauchy problem

An analytic proof of the product formulas for Bessel, Whittaker, and Jacobi functions is given which are due to Sonine (1880), Watson and Glaeske (1939/1981), and Koornwinder (1972), respectively. The proof is based on the approach of Delsarte (1936) to generalized translation operators via the solution of an associated Cauchy problem. The main step in solving this problem is to determine the associated Riemann function. In all three cases, the characteristic boundary value problem for the Riemann function can be transformed into a normal form for which the solution is known. This leads to an explicit representation of the Riemann functions associated with the Bessel, Whittaker, and Jacobi differential operators by means of which the kernels of the corresponding translation operators are then calculated.

P. R. MASANI:

Fourier transformation as integration with respect to a vector measure

Let Γ be a l.c.a. group, $\mathcal{B}$ be the class of Borel subsets and m be Haar measure thereon, let $\Gamma^\wedge, \mathcal{B}^\wedge, m^\wedge$ be the dual entities, and $\mathcal{B}_m = \{B \in \mathcal{B}: m(B) < \infty\}$. For $B \in \mathcal{B}_m$ let $\xi(B) = 1_B^\vee$, where $1_B^\vee(\lambda) = \int_B \lambda(t) m(dt)$, $\lambda \in \Gamma^\wedge$. Then ξ is a countable-additive measure on the δ-ring $\mathcal{B}_m$ with values in the Banach spaces $L_{p'}(\Gamma^\wedge)$, $1 \leqslant p \leqslant 2$. Write $\xi_{p'}$ for ξ when the $L_{p'}(\Gamma^\wedge)$ topology is used on its range. Then the class $L_{\xi_{p'}}(\Gamma)$ of $\xi_{p'}$-integrable functions on Γ satisfies $L_{\xi_{p'}}(\Gamma) \supseteq L_p(\Gamma)$, and for $f \in L_p(\Gamma)$, $\int_\Gamma f(t)\xi(dt) = f^\vee$, the Fourier transform (FT) of f in the Hausdoff-Young sense. This extends the $p = 2$ case done in 1969 [Abstract Spaces & Approximation, P.L. Butzer & B. Sz.-Nagy, Birkhäuser, 162-182] . If the last equality is adopted as the definition of the FT $f^\vee$ of $f \in L_{\xi_{p'}}(\Gamma)$, we get a unified theory of the FT for $1 \leqslant p \leqslant 2$ without improper integration. Although one has $L_2(\Gamma) = L_{\xi_2}(\Gamma)$ it transpires that $L_p(\Gamma) \subsetneqq L_{\xi_p}(\Gamma)$ for $1 < p < 2$. This raises some interesting new questions.

D. H. MUGLER:

Green's functions for the finite difference heat, Laplace, and wave equations

In this paper, representations are developed for the Green's functions for a partial difference formulation of an initial-value problem that includes the half-plane heat (diffusion), Laplace, and wave equations as special cases. Solutions of the partial difference equation are shown to be given by a discrete convolution, analogous to integral representations for the continuous case. A convergence property relating each discrete Green's function to the Green's function of its associated partial differential equation is also presented.

J. MUSIELAK:

Some embedding theorems for modular classes

In 1961 W. Matuszewska obtained results concerning connections between $\bigcap_{i=1}^{\infty} L^{\varphi_i}\langle a,b\rangle$, $\bigcup_{i=1}^{\infty} L^{\varphi_i}\langle a,b\rangle$ and $L^{\psi}\langle a,b\rangle$ for Orlicz classes. These results were generalized 1974 and 1977 by A. Waszak and myself to Orlicz classes with functions φ depending on a general parameter ξ in place of index i, ξ running over a set Z. Here, the results are extended to the case of general concave and convex functionals in place of integrals over sets Z.

R. J. NESSEL:

Some negative results in connection with Marchaud-type inequalities

Continuing our previous investigations on quantitative uniform boundedness principles, the present paper, which represents joint work with W. Dickmeis and E. van Wickeren, is concerned with some negative results in connection with Marchaud-type inequalities. The existence of the relevant counterexamples follows by means of a general theorem, given in terms of operators in Banach spaces. The method of proof essentially consists in a quantitative version of the familiar gliding hump method.

P. NEVAI:

Two of my favorite ways of obtaining asymptotics for orthogonal polynomials

Improvements of the continuous and discrete Liouville - Steklov method for proving asymptotic formulas for orthogonal polynomials are discussed, and a short survey of recent asymptotic results is given.

J. PEETRE:

Invariant Banach spaces connected with the holomorphic discrete series

First the theory of Möbius invariant spaces of holomorphic functions in the disk, as developed by Arazy, Fisher, Rubel, Timoney, and others are summerized. Then more general group actions connected with the holomorphic discrete series are considered from a similar point of view. Finally assorted applications are given: Hankel operators (new proof and generalization of Peller's theorem), rational approximation, Shields's Riesz-Fejér inequality, etc. This is joint work with Jonathan Arazy, Steve Fisher, and Svante Janson.

F. PEHERSTORFER:

Extremalpolynome in der L^1- und L^2-Norm auf zwei disjunkten Intervallen

Sei $-1 < \alpha \leqslant \beta < 1$. p_n bezeichne das Orthogonalpolynom bzgl. der Gewichtsfunction

$$w(x) = \begin{cases} ((x-\alpha)/(1-x^2)(x-\beta))^{1/2} & \text{für } x \in (-1,\alpha) \cup (\beta,1) \\ 0 & \text{für } x \in (\alpha,\beta). \end{cases}$$

Für die Rekursionskoeffizienten von p_n wird eine Rekurrenzrelation angegeben. Mit Hilfe des Orthogonalpolynoms p_n werden dann jene Polynome $P_n = x^n + \ldots$ bestimmt, die bezüglich der L^1-Norm auf $[-1,\alpha] \cup [\beta,1]$ am wenigsten von Null abweichen.

R. S. PHILLIPS:

The spectrum of the Laplacian for domains in hyperbolic space

This talk is concerned with the spectrum of the Laplace-Beltrami operator acting in domains with the finite geometric property and of infinite volume in real hyperbolic space H^{n+1}. In such domains the Laplacian has a discrete spectrum in the interval $[0,(n/2)^2)$ and an absolutely continuous spectrum in $[(n/2)^2, \infty)$. Discrete subgroups of motions have fundamental domains of this sort where the lowest eigenvalue is closely related to the Hausdorff dimension of the limit set and the counting number for orbits of points. A lower bound on this value is obtained from the lowest eigenvalue for the Laplacian with free boundary conditions. Its existence or nonexistence is investigated as well as its continuity under deformations, especially degenerate types of deformations. It is shown that the Hausdorff dimension of the limit sets of a discrete group of motions in $\mathbb{R}^n$, $n \geq 3$, generated by inversions in a finite number of mutually exterior spheres cannot be made arbitrarily close to n. Finally a complete representation for the Laplacian is obtained in terms of the Radon transform. These results were obtained in collaboration with Peter Sarnak and Peter Lax.

R. S. PHILLIPS:

Recollections

A report on my early career, born on June 23,1913, in Los Angeles, Professor of Mathematics at Stanford University since 1960.

C. R. PUTNAM:

Positive commuting perturbations of selfadjoint operators and hyponormality

Let P be a selfadjoint operator on a separable, infinite dimensional Hilbert space. Then there exists a completely hyponormal operator T having a polar factorization $T = UP$, U unitary, and satisfying the condition that T^*T and TT^* commute, if and only if (1) $P \geq 0$ and $\sigma(P)$ contains at least 2 points, (2) 0 is not in $\sigma_p(P)$, and (3) whenever $\sigma_p(P)$ is not empty, neither $\sup \sigma_p(P)$ nor $\inf \sigma_p(P)$ belongs to $\sigma_p(P)$ with a finite multiplicity.

P. RÉVÉSZ:

Estimation of the regression function via orthogonal expansion

Our goal is to estimate a regression function $r(x) = E(Y|X=x)$ $(0 \leq x \leq 1)$ from an independent sample of size n. We propose a sequence of estimators $\hat{c}_k$ of the Fourier coefficients $c_k = \int_0^1 r(x)\, \varphi_k(x)\, dx$ of $r(x)$ (where $\{\varphi_k(x)\}$ is a complete, orthonormal sequence satisfying some regularity conditions) and prove that $\hat{c}_k \to c_k$ with probability one for any k as $n \to \infty$. We also investigate the L^2 distance between the estimate $r_n(x) = \sum_{k=1}^{N_n} \hat{c}_k\, \varphi_k(x)$ and $r(x)$ where N_n is a suitable sequence of integers.

S. D. RIEMENSCHNEIDER:

n - widths of smoothness spaces

In this lecture we survey the known results for the asymptotics of the n - widths of the unit ball $U(W_p^\alpha)$ in the Sobolev space W_p^α as measured in L_q, $1 \leq p \leq \infty$, $0 < q \leq \infty$, $\alpha > 1/p - 1/q$. Using the C_p^α spaces intoduced by R. DeVore and R. C. Sharpley, which agree with the Sobolev spaces for integer α and $1 < p \leq \infty$, we can extend these results to include the case when $0 < p < 1$. Using embeddings between C_p^α spaces and Besov spaces, this method also gives n-width results for the Besov spaces $B_p^{\alpha,q}$ if $0 < p < 1$.

J. ROVNYAK:

Some extremal problems with constraints

Let D be the unit disk in the plane, and σ the normalized Lebesgue measure on $\Gamma = \partial D$. Fix $0 \leqslant w \in L^\infty(\sigma)$. By an optimal approximant to $h \in L^2(w d\sigma)$ we mean any $\hat{k} \in H^2(D)$ such that $\int_\Gamma |h-\hat{k}|^2 w d\sigma \leqslant \int_\Gamma |h-k|^2 w d\sigma$ for all $k \in H^2(D)$ with $\|k\|_2 \leqslant \|\hat{k}\|_2$. Then the optimal approximants to $e^{-i\theta}$ are given by $\{k_\lambda\}_{\lambda > 0}$, if $w \notin L^1(\sigma)$, and $\{k_\lambda\}_{\lambda \geqslant 0}$, if $w \in L^1(\sigma)$, where $k_\lambda(z) = (1 - c_\lambda(0)/c_\lambda(z))/z$,

$$c_\lambda(z) = \exp\{\frac{1}{2} \int_\Gamma \frac{e^{i\theta}+z}{e^{i\theta}-z} \log[\,w(e^{i\theta})+\lambda\,]\, d\sigma\}.$$

This yields the following refinement of Szegö's infimum: For $\lambda > 0$

$$\min \int_\Gamma |e^{-i\theta}-k|^2 w d\sigma = \exp\{\int_\Gamma \log(w+\lambda) d\sigma\} \int_\Gamma \frac{w d\sigma}{w+\lambda},$$

where the minimum is taken over all $k \in H^2(D)$ for which

$$\|k\|_2^2 \leqslant \exp\{\int_\Gamma \log(w+\lambda) d\sigma\} \int_\Gamma \frac{d\sigma}{w+\lambda} - 1.$$

The unique extremal function is given by k_λ. A similar result is obtained relative to Kolmogorov's infimum.

D. C. RUSSELL:

Spline interpolation of power-dominated data

Let (x_k) be a bi-infinite knot sequence for which the mesh-ratio is smaller than any exponential order (in particular, the local mesh ratio must be finite, but the global mesh ratio may be infinite). Let ρ be a non-negative real number, and (y_k) a (real or complex) data sequence for which $y_k = O(|x_k|^\rho)$ as $k \to \pm\infty$. We prove the existence and uniqueness of a spline function of any previously specified odd degree, with simple knots (x_k), which interpolates (y_k) and which is dominated by exactly the same power, namely $S(t) = O(|t|^\rho)$ as $t \to \pm\infty$. We may replace O by o throughout. We also obtain a series representation for $S(\cdot)$ in terms of (y_k) and of a sequence of "fundamental splines" $L_k(\cdot)$ which decay exponentially near $\pm\infty$. The results generalize theorems of Schoenberg and de Boor. (Joint work with M. Stieglitz (Karlsruhe)).

R. B. SAXENA:

Uniform convergence of some poised problems of Hermite-Birkhoff interpolation

In this paper we study a special Hermite-Birkhoff interpolation problem which is similar to (0,2,3) interpolation. It consists of finding a polynomial $p_n(X,x)$ of degree at most $2n+1$ such that $p_n^{(j)}(X,x_i) = f_i^{\,j}$ $(i=1,\ldots,n; j=0,2,3)$ for an arbitrary given set of real nodes X: $-1 \leq x_n < \ldots < x_1 \leq 1$ and arbitrary real numbers $f_1^{\,j},\ldots$ $\ldots, f_n^{\,j}$ $(j=0,2,3)$. We call it quasi-(0,2,3) interpolation. First we construct the interpolation in an explicit form and then prove a theorem which gives a sufficient condition under which the quasi-(0,2,3) interpolation for every $f \in C^2[-1,1]$ converges uniformly on $[-1,1]$. The error estimates for Tchebycheff nodes are derived. (Joint work with H. C. Tripathi).

W. SCHEMPP:

Funktionalanalytische Aspekte der Radarortung und digitalen Signalübertragung

Im Vortrag wird gezeigt, daß die Darstellungstheorie (d.h. die Mackey-Maschinerie oder, in geometrischer Formulierung, die Kirillov-Korrespondenz) der reellen nilpotenten Heisenberg-Gruppe $\tilde{A}(\mathbb{R})$ im Schnittpunkt der Quantenmechanik, der Theorie der analogen

Signale (Radarortung) und der Theorie der digitalen Signale (Abtasttheorem) liegt. Diese Theorie ermöglicht insbesondere die Untersuchung der Symmetrieeigenschaften der Radar-Unschärfeflächen. Mit Hilfe der unitären Oszillatordarstellung der metaplektischen Gruppe $M_p(1,\mathbb{R})$ lassen sich dann die zugehörenden erzeugenden Impulseinhüllenden explizit berechnen. Auf Anwendungen der harmonischen Analyse der endlichen nilpotenten Heisenberg-Gruppe in der numerischen Mathematik wird abschließend kurz hingewiesen.

F. SCHIPP:

Martingales, bases, Hardy spaces, and a.e. convergence

A survey on martingale Hardy spaces is given. Some new results are presented with respect to some special martingales with non-linearly ordered index sets. Estimations with respect to such martingales are connected with the a.e. convergence of Walsh-Fourier series. A new example of a separable Banach space of VMO-type is given, which does not have a Schauder basis.

G. SCHMEISSER:

Reconstruction of entire harmonic functions from given values

According to a result of Carlson (1914), an entire function f of exponential type less than τ is uniquely determined by its values at the points $n\pi/\tau$ $(n=0, \pm 1, \pm 2, \ldots)$. The reconstruction of f from these values is of special interest to engineers (keyword "Sampling Theorem"). R. P. Boas observed that the situation changes if we consider an entire harmonic function of exponential type less than τ. He proved that such a function u is uniquely determined by its values at the lattice points $n\pi/\tau$, $(i+n)\pi/\tau$ $(n=0,\pm 1,\pm 2,\ldots)$ and asked for the reconstruction of u from these values. We give an answer to this question thereby improving on an earlier approach of Ching and Chui and also solving another problem of Boas. (Joint work with R. Gervais and Q. I. Rahman).

BL. SENDOV:

Averaged moduli of smoothness

The purpose of the paper is a new approach for estimating the error in a large number of numerical methods, such as interpolation, approximation of functions by means of operators, quadrature formulae, network methods of solution of integral and differential equations, etc. These new characteristics of functions are named averaged moduli of smoothness or τ-moduli. They are meaningful for every bounded function being an integral analogue of the classical moduli of continuity and smoothness for the uniform metric, so-called ω-moduli. The novelity in our approach is the different way of conveying an analogue of the uniform case.

BL. SENDOV:

To Academician L. Iliev on the occasion of his 70th anniversary

A report on the life of Academician Lyubomir Iliev, born on April 20, 1913, in Veliko Tarnovo, Professor of Mathematics at the University of Sofia since 1952.

H. S. SHAPIRO:

Exact quadrature identities for analytic and harmonic functions

One is concerned here with identities of the type $\int_\Omega u\,dx = \int u\,d\mu$, where Ω is a domain in $\mathbb{R}^d$ and μ is a measure with compact support in Ω. In the most typical case μ is a finite linear combination of "delta" measures. The identity is to hold for all u harmonic and integrable over Ω (simplest example: the mean-value formula for harmonic functions on a ball Ω). A new approach to such identities is presented, based on a (known) characterization of distributions in Ω which annihilate harmonic functions. It implies many known results and leads to new ones, especially in the absence of boundedness assumptions on Ω.

R. C. SHARPLEY:

Interpolation of $H^1(\mathbb{R})$ and $H^\infty(\mathbb{R})$

A Banach space X is called an interpolation space of a Banach couple (X_1,X_2) if each admissible operator (i.e., $T|_{X_i}$ is a bounded operator on X_i, $i=1,2$) is bounded on X. Calderón characterized the interpolation spaces for (L^1,L^∞) as Banach lattices of measurable functions which satisfy the property

$$(*) \quad g \prec f \text{ and } f \in X \Rightarrow g \in X \text{ and } \|g\|_X \leq c\|f\|_X .$$

We show that the interpolation spaces for the Hardy spaces (H^1,H^∞) can be characterized as the Hardy spaces of all such X which satisfy (*). The proof uses recent results of P. Jones (on L^∞ estimates for solutions of $\bar{\partial}F=\mu$, where μ is a Carleson measure) and of Brudnyi-Krugljak (on K monotone spaces). A rephasing of the result is that the interpolation spaces for $(\mathrm{Re}\,H^1, \mathrm{Re}\,H^\infty)$ can be characterized as the spaces $\mathrm{Re}\,H(X)=\{f\in X$: the Hilbert transform of $f\in X\}$.

R. L. STENS:

The cardinal interpolation series

If f is an entire function of exponential type $\leq \sigma\pi$, integrable over the real axis, then it has the representation

$$(*) \quad f(t) = \sum_{k=-\infty}^{\infty} f\left(\frac{k}{\sigma}\right) \frac{\sin \pi(\sigma t-k)}{\pi(\sigma t-k)} .$$

If f is not such a function, then (*) may hold at least in the limit for $\sigma\to\infty$. The aim of the talk is to give some conditions implying

$$f(t_o) = \lim_{\sigma \to \infty} \sum_{k=-\infty}^{\infty} f(\frac{k}{\sigma}) \frac{\sin \pi(\sigma t-k)}{\pi(\sigma t-k)}$$

for a fixed $t_o \in \mathbb{R}$. Moreover, the connection between (*), the Poisson summation formula and the Cauchy integral formula is studied.

J. SZABADOS:

Polynomial approximation on disjoint intervals

A general classical result of J. L. Walsh ensures the possibility of approximation of certain types of functions by polynomials on disjoint finite intervals. Nevertheless, this result is not constructive and, in general, it does not give concrete information on the order of convergence. Starting from a recent result of C. K. Chui and M. Hasson we prove a convergence estimate for the set $[-b,-a] \cup [a,b]$ $(0 < a < b)$, when besides analyticity, the function satisfies some smoothness condition on the boundary. The norms of the best approximating polynomials on $[-a,a]$ are also estimated from both sides. A generalization of the convergence theorem for more than two disjoint intervals of possibly different lengths is also given.

K. TANDORI:

Über die Mitten von orthogonalen Funktionen

Es wird die Konvergenz der Mitten

$$(*) \qquad \{ \frac{1}{\lambda_n} \sum_{k=1}^{n} a_k \varphi_k(x) \}_{n=1}^{\infty}$$

betrachtet, wobei $\lambda = \{\lambda_k\}_1^{\infty}$ eine monoton wachsende, ins Unendliche strebende Folge von positiven Zahlen, $a = \{a_k\}_1^{\infty}$ eine reelle Zahlen-folge und $\varphi = \{\varphi_k(x)\}_1^\infty$ ein reelles orthonormiertes System im Intervall $(0,1)$ sind. Für $1 \leq K \leq \infty$ sei $\Omega(K)$ die Klasse der reellen, orthonormierten Systeme φ in $(0,1)$ mit $|\varphi_k(x)| \leq K$ $(x \in (0,1);\ k = 1,2,\ldots)$. Dann können z.B. die folgenden Sätze bewiesen werden:

I. Für jedes K $(1 \leq K \leq \infty)$ gibt es eine Klasse $M(K,\lambda)$ von Folgen a mit folgender Eigenschaft: Ist $a \in M(K,\lambda)$, dann konvergiert die Folge (*) für jedes $\varphi \in \Omega(K)$ in $(0,1)$ fast überall. Ist aber $a \notin M(K,\lambda)$, dann gibt es ein $\varphi \in \Omega(K)$ derart, daß die Folge (*) in $(0,1)$ überall divergiert.

II. Für jedes $1 < K < \infty$ gilt $M(1,\lambda) = M(K,\lambda) \subsetneq M(\infty,\lambda)$.

V. TOTIK:

The necessity of a new kind of modulus of smoothness

A new kind of modulus of smoothness is introduced and applied to different approximation problems. It very much resembles the ordinary moduli of smoothness, only the increment in it varies together with the variable (see below). The applications include the characterization of best polynomial approximation, exact estimates on the rate of approximation by positive or contraction operators, inverse theorems, as well as the characterization of the K-functional between L^p and the corresponding weighted Sobolev space (with a given weight). As an illustration let us mention the equivalence of $E_n[f]_{L^p[-1,1]} = O(n^{-\alpha})$ and $\|\Delta^r_{h\varphi} f\|_{L^p[-1,1]} = O(h^{-\alpha})$ for $\varphi(x) = (1-x^2)^{1/2}$, $0 < \alpha < r$.

R. S. VARGA:

On the Bernstein conjecture

Let $E_n(|x|)$ denote the best uniform approximation to $|x|$ by polynomials of degree at most n on the interval $[-1,1]$. Then, from Jackson's theorem, (*) $E_n(|x|) \leq 6/n$ for all $n \geq 1$. Since $|x|$ is even in $[-1,1]$, then $E_{2n}(|x|) = E_{2n+1}(|x|)$ so that we only consider even n. In 1914,

S. Bernstein proved that there exists a constant $\beta > 0$ such that $\lim_{n\to\infty} 2nE_{2n}(|x|) = \beta$, which is sharper than (1). Moreover, he determined upper and lower bounds for β whose average is the first three decimal digits of $1/(2\sqrt{\pi}) = 0.282\ 094\ 792 \ldots$. This became known as the Bernstein conjecture: Is $\beta = 1/(2\sqrt{\pi})$? We show that this conjecture is false by determining β to approximately 80 decimal digits, i.e.,

$$\beta = 0.280\ 169\ 499\ 023\ 869\ 133 \ldots$$

P. VÉRTESI:

Some recent results on the divergence of Lagrange interpolation

For $f \in C[0,1]$ let $L_n(f,X,x)$ be the Lagrange interpolatory polynomial of degree $\leq n-1$ with interpolatory matrix $X = \{x_{kn}\} \subset [-1,1]$. For an abstract modulus of continuity ω let $C(\omega) = \{f; \omega(f,t) = O(\omega(t))\}$, $C^*(\omega) = \{f; \omega(f,t) = o(\omega(t))\}$, where $\omega(f,t)$ denotes the modulus of continuity of f. Then the main result states that there exists $f_\omega \in C(\omega)[f_\omega \in C^*(\omega)]$ such that $\overline{\lim}\ |L_n(f,X,x) - f(x)| \geq 1$ $[\overline{\lim}|L_n(f,X,x)| = \infty]$ on a dense set of second category provided that $\underline{\lim}\ \omega(1/n)\log n > 0$ $[\underline{\lim}\ \omega(1/n)\log n = \infty]$.

In joint work with J. Szabados the generalization of the Erdös - Vértesi theorem for infinite intervals is shown, i.e., for $X \subset \mathbb{R}$ there exists a continuous function F on $\mathbb{R}$ such that $\overline{\lim}\ |L_n(F,X,x)| = \infty$ a.e. on $\mathbb{R}$.

L. ZSIDÓ:

On the generation of one - parameter operator groups

Let $\alpha = (\alpha_t)_{t \in \mathbb{R}}$ be an appropriately continuous one - parameter group of continuous linear operators in a Banach space X. The analytic generator α_{-i} of α is defined by: $(x,y) \in \text{graph}\ (\alpha_{-i}) \Leftrightarrow$ the function $t \to \alpha_t(x)$, $t \in \mathbb{R}$, has a continuous extension on $\{z \in \mathbb{C};\ -1 \leq \text{Im}\ z \leq 0\}$, being analytical in the interior, whose value in $-i$ is y. If X is a Hilbert space and the α_t's are unitaries, then α_{-i} is an injective positive selfadjoint operator, and α_t is the (it)-th power of α_{-i}. If X is a von Neumann algebra and the α_t's are *-automorphisms, then in the majority of the cases the spectrum of α_{-i} is the whole complex plane; so α_{-i} has bad spectral properties. However, in this case acceptable characterizations can be given; they are useful in the quantum field theory.

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