Prague Hamburg Freiberg

Noncommutative Algebras and Applications

Goslar, Germany, 2015, June 14 until June 16

to be held in the Haus am Steinberg

Zeppelinstraße 1, 38640 Goslar

List of Abstracts

Contents

1 Zainab R. Al-Yasiri: On a boundary value problem for a p-Dirac equation

Z. R. Al-Yasiri, K. Gürlebeck
Bauhaus University Weimar, Germany
Faculty of Civil Engineering/Institute of Mathematics/Physics.

The p-Laplace equation is a nonlinear generalization of the Laplace equation. This generalization is often used as a model problem for special types of nonlinearities. The p-Laplace equation can be seen as a bridge between very general nonlinear equations and the linear Laplace equation. The aim of this paper is to solve the p-Laplace equation for $1 < p < 2$ and to find strong solutions. The idea is to apply a hypercomplex integral operator and spatial function theoretic methods to transform the p-Laplace equation into the p-Dirac equation. This equation will be solved iteratively by using a fixed point theorem. Applying operator-theoretical methods for the p-Dirac equation and p-Laplace equation the existence and uniqueness of solutions in certain Sobolev spaces will be proved.

2 Francesco Antonuccio: Split-quaternions and the Dirac equation [canceled]

Francesco Antonuccio
London, United Kingdom

We show that Dirac 4-spinors admit an entirely equivalent formulation in terms of 2-spinors defined over the split-quaternions. In this formalism, a Lorentz transformation is represented as a 2×2 unitary matrix over the split-quaternions. The corresponding Dirac equation is then derived in terms of these 2-spinors. In this framework the $SO(3,2;\mathbf{R})$ symmetry of the Lorentz invariant scalar $\overline{\psi}\psi$ is manifest.

References

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3 Swanhild Bernstein: Fractional Riesz-Hilbert transforms and fractional monogenic signals

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Institute of Applied Analysis

The analytic signal was proposed by Gabor as a complex signal corresponding to a given real signal. The Hilbert transform is the key component in Gabor's analytic signal construction. The analytic signal has been generalized the monogenic signal by Felsberg and Sommer based on Clifford analysis. Fractional transformations are widely used in optics and based on applied needs as well as a mathematical constructions based on eigenvalue decompositions. The fractional Hilbert transform and associated signal constructions are based on rotations as they are used by Lohmann. We will generalize the fractional Hilbert transform to the quaternionic fractional Riesz-Hilbert transform and constructed based on that the quaternionic fractional monogenic signal. The constructions has already been applied in optics.

References

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[4] Venkitaraman, A., Seelamantula, C.S.: *Fractional Hilbert transform extensions and associated analytic signal construction.* Signal Processing, **94** (2014), 359–372.

[5] Heise, B. et al: *Fourier Plane Filterung revisited – Analogies in Optics and Mathematics,* Sampling theory in Signal and & Image Processing, 13(3), (2014), 231–248.

4 Sebastian Bock: Monogenic series expansions and an application to linear elasticity

Sebastian Bock
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Institute of Mathematics & Physics

In the talk we shall give a brief overview of some interesting characteristics of recently studied orthogonal Appell bases [1, 2] of solid spherical monogenics in $\mathbb{R}^3$. In this context, a compact closed form representation of the Appell basis elements in terms of classical spherical harmonics is shown. Based on a recently developed spatial generalization of the Kolosov-Muskhelishvili formulae in terms of a monogenic and an anti-monogenic function [3], the Appell basis is used to construct a polynomial basis of solutions to the Lamé equation from linear elasticity. Finally, a hypercomplex version of the classical Kelvin solution which describes the elastic displacements of a concentrated force acting at the origin of an infinite body is discussed.

References

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[3] Weisz-Patrault, D.; Bock, S. and Gürlebeck, K.: *Three-dimensional elasticity based on quaternion-valued potentials*, International Journal of Solids and Structures, Volume 51, Issues 19â20, pages 3422â3430, 2014.

5 Fred Brackx: Symplectic quaternionic Clifford analysis

Fred Brackx, Hennie De Schepper
Ghent University, Belgium

David Eelbode
University of Antwerp, Belgium

Roman Lávička, Vladimír Souček
Charles University, Prague, Czech Republic

A fundamental result when establishing a function theory is the Fischer decomposition of spaces of homogeneous polynomials with respect to irreducible representations of a symmetry group. The symmetry groups for standard (or Euclidean) Clifford analysis in $\mathbb{R}^m$ and hermitian Clifford analysis in $\mathbb{R}^{2n}$ are the $\mathrm{Spin}(m)$ and the $\mathrm{U}(n)$ groups respectively. The object of this talk is the decomposition of spaces of spinor–valued homogeneous polynomials in $\mathbb{R}^{4p}$, and in particular spaces of spinor–valued spherical harmonics in $\mathbb{R}^{4p}$, in terms of irreducible representations of the symplectic group $\mathrm{Sp}(p)$. These Fischer decompositions involve spaces of homogeneous $\mathfrak{osp}(4|2)$–monogenic polynomials, the Lie super algebra $\mathfrak{osp}(4|2)$ being the Howe Dual to the symplectic group $\mathrm{Sp}(p)$. This new concept of $\mathfrak{osp}(4|2)$–monogenicity has to be introduced as a refinement of quaternionic monogenicity in order to obtain $\mathrm{Sp}(p)$–irreducibility; it is defined by means of the four quaternionic Dirac operators, a scalar Euler operator $\mathcal{E}$ underlying the notion of simplectic harmonicity and a multiplicative Clifford algebra operator P underlying the decomposition of spinor space into so–called symplectic cells. The operators $\mathcal{E}$ and P, and their hermitian conjugates, arise naturally when constructing the Howe Dual Pair $\mathfrak{osp}(4|2) \times \mathrm{Sp}(p)$, the action of which makes the Fischer decomposition multiplicity–free.

6 Rolf Dahm: Some more remarks on rank 3-Lie algebras in physics

Rolf Dahm
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Beratung für IS

We summarize some previous work on SU(4) describing hadron representations and transformations as well as its noncompact 'counterpart' SU$*$(4) being the complex embedding of Sl(2,**H**). So after having related the 16-dim Dirac algebra to su*(4), on the one hand we have access to real, complex and quaternionic Lie group chains and their respective algebras, on the other hand it is of course possible to relate physical descriptions to the respective representations. With emphasis on the common maximal compact subgroup USp(4), we are led to projective geometry of real 3-space and various transfer principles which we use to extend previous work on the rank 3-algebras above. On real spaces, such considerations are governed by the groups SO(n,m) with $n + m = 6$. The central thread, however, focuses on line and Complex geometry which finds its well-known counterparts in descriptions of electromagnetism and special relativity as well as - using transfer principles - in Dirac, gauge and quantum field theory.

References

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7 Klaus Gürlebeck: Clifford operator calculus for boundary value problems of micropolar elasticity

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Chair of Applied Mathematics
D. Legatiuk
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This contribution presents the application of the Clifford operator calculus to boundary value problems of micropolar elasticity, which is a refined theory of elasticity including not only force stresses, but also moment stresses. This theory plays a significant role for boundary value problems of elasticity which lead to high gradients of stresses.

8 Mijail Guillemard: On noncommutative algebras in data analysis

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We present some strategies on how to use noncommutative algebras in signal and data analysis. We begin with a basic review of ideas in signal processing using frame theory as a main tool that generalizes time-frequency analysis and wavelets transforms. Manifold learning and dimensionality reduction are subsequently introduced as modern tools for data analysis. A related topic is persistent homology, which provides new analysis strategies using concepts from homology. With this background, we explain how noncommutative algebras might be of interest for studying datasets in modern application fields.

9 Angela Hommel: Finite differences as useful tool for solving problems in fracture mechanics

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It is well-known that the solution of the elastic fundamental equations of a homogeneous isotropic material in plane stress and strain state can be equivalently reduced to the solution of the biharmonic equation. The Theorem of Goursat is the link between linear elasticity theory and complex function theory. This theorem proves that the solution of the biharmonic equation can be represented by the help of two holomorphic functions. As further tool power series and Laurent series approaches are used in order to construct the solution of the differential equation in elasticity theory. All these steps are very important in the field of fracture mechanics, where stress and displacement fields in the neighborhood of singularities caused by cracks and notches have to be calculated. Using the series expansion of the holomorphic functions the order of singularity can be reproduced exactly and important mechanical characteristics can be determined. The described method, the so-called theory of complex stress functions, goes back to Kolosov and Muskhelishvili.
At the conference results can be presented, which describe the relation between linear elasicity theory and complex function theory on the basis of finite differences. The well-known forward and backward differences are used in order to define difference operators and to describe discrete harmonic and discrete holomorphic functions. The proof of the theorem of Goursat is an important step also in the discrete theory. In the field of complex function theory discrete polynomials are introduced, which fulfill the so-called Appell property. These polynomials form the basis in order to work with finite sums in finite dimensional domains.

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10 Jakub Krásenský: Quaternions and positional numeral systems

Jakub Krásenský
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Faculty of Nuclear Sciences and Physical Engineering

In the first part of the talk the general concept of position numeral systems will be discussed with focus on the so-called canonical number systems. As an important example the Penney system with radix $-1 + \mathrm{i}$ in the ring of Gaussian integers will be introduced and the fact that it is a canonical number system will be proved. In the second part position numeral systems in quaternions will be explored, in particular in the ring of Hurwitz integers. Canonical number systems with the smallest possible alphabet will be described. For every Hurwitz integer it will be determined whether it can or cannot serve as a radix of some number system.

References

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Acknowledgments: We acknowledge financial support by the Student Grant Agency SGS14/205/OHK4/3T/14.

11 Dmitri Legatiuk: Application of pseudo-complex powers to interpolation in $\mathbb{R}^3$

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Pseudo-complex powers (or pseudo-complex polynomials, PCP) are 3D monogenic polynomials which are isomorphic to the integer powers of one complex variables. This contribution deals with an application of PCP-basis to a problem of interpolation in $\mathbb{R}^3$ for some canonical domains.

12 Helmuth R. Malonek: Starting with pseudo-complex powers: numerical and combinatorial aspects

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Center for Research and Development in Mathematics and Applications

Due to the use of non-commutative algebras in hypercomplex function theory a large variety of different representations of hypercomplex polynomials adapted to different concrete problems and depending on different variables have been studied. Naturally arises the question of their relationships and advantages or disadvantages in numerical applications. Starting with pseudo-complex powers (see [1] or [2]), we show that the inner structure of hypercomplex polynomials reveals also interesting combinatorial relations and often relates to particularly important sets of numbers as, for example, central binomial coefficients, Bernoulli or Sterling numbers etc.

References

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13 Steve Mudute-Ndumbe: Random matrix ensembles with split-complex and split-quaternionic elements

Eva-Maria Graefe, Steve Mudute-Ndumbe and Matthew Taylor
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In this talk we construct new ensembles of random matrices on the spaces of split-complex and split-quaternionic matrices. We give a brief introduction to Random Matrix Theory, exploring the relevance of the field and examining properties of some of the classical Gaussian ensembles. We then build our ensembles using similar assumptions to those used for the pre-existing ensembles, and compare some of the similarities and differences. We derive explicit results for the spectral densities of our new ensembles in the 2 x 2 case, and numerically identify properties in the more general N x N case. Finally, we relate these new ensembles to so-called PT-Symmetric Quantum Mechanics, which has been attracting considerable interest recently.

14 Hung Manh Nguyen: Notes on ψ-hyperholomorphic functions in $\mathbb{R}^3$

Hung Manh Nguyen
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The theory of ψ-hyperholomorphic functions was proposed as a generalization of the classical monogenic function theory by replacing the set of the standard orthonormal vectors in $\mathbb{R}^n$ by a structural set ψ. Recent studies have succeeded in using ψ-hyperholomorphic functions for the treatment of several problems arising from the theory of monogenic functions. In this talk, we will present some progresses on this line of research.

References

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[3] Gürlebeck, K., Nguyen, H. M. and D. Legatiuk, D.: *An additive decomposition of harmonic functions in $\mathbb{R}^3$*, Computational Science and Its Applications – ICCSA 2014, Lecture Notes in Computer Science (LNCS), **8579** (2014), 189–203.

Acknowledgments: The author would like to thank MOET-Vietnam for the financial support.

15 Dixan Peña Peña: The Hermitian submonogenic system

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Hermitian Clifford analysis revolves around the study of Dirac-like systems in several complex variables and the main concept in this function theory is that of the h-monogenic functions [1]. In this talk we shall introduce a new system whose solutions, called Hermitian submonogenic [2], are an extension of the h-monogenic functions. For this system we studied the Cauchy-Kowalevski extension showing that its solutions are determined by their Cauchy data and we solved the system explicitly for the Gaussian and for other special functions as well. In this way, we obtained Hermitian Bessel functions, Hermite polynomials and generalized powers. We also derived a Vekua-type system that describes all axially symmetric solutions.

References

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16 Susanne Pumplün: Factoring skew polynomials over Hamilton's quaternion algebra and the complex numbers [canceled]

Susanne Pumplün
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We show that all non-constant polynomials in the skew-polynomial ring $\mathbb{H}[t;\sigma,\delta]$ over Hamilton's quaternions $\mathbb{H}$ (or more generally, over the quaternion division algebra over any real closed field) decompose into a product of linear factors, and that all non-constant polynomials in the skew-polynomial ring $\mathbb{C}[t;\sigma,\delta]$ decompose into a product of linear and quadratic irreducible factors. Our proofs use nonassociative algebras constructed out of skew-polynomial rings as introduced by Petit, [1].

References

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17 Bernd Schmeikal: Real quaternions - and logic space algebra from nothing

Bernd Schmeikal
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Hamilton′s quaternions are not the only ones. There are some more real 4-dimensional algebras, as for example the Tessarines known to us as bi-complex numbers or some commutative Quaternions as were proposed by Segre. Recently Gerhard Opfer had pointed out that besides Quaternions, Coquaternions, Tessarines and Cotessarines there are four additional algebras on an equal footing. He assumed that those four new algebras are in a way equivalent with the known ones and can be derived from them. In a recent article I had shown that this guess is right. Then, Wolfgang Sproessig supposed that all the eight different types of Quaternions can somehow be affiliated to one mother algebra. This supposition is also true. The eight types can be led back to the commutative algebra of the Cotessarines. Using the wonderful concept of Iterant algebra as was invented by Louis Kauffman, we can split ′Nothing′ into two iterant views or polarity strings and by two symmetry operations we can bring forth logic space and the algebra of space-time as we know from quantum physics.

18 Baruch Schneider: On quaternionic boundary value problems

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Baruch Schneider
Izmir University of Economics, Izmir, Turkey

In this talk we discuss the some boundary value problems based on complex quaternionic analysis.

19 Caterina Stoppato: Zeros of polynomials and slice regular functions over alternative *-algebras

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Over the last century, the roots of (unilateral) quaternionic polynomials have been analyzed and understood in detail. Then the work of Gentili and Struppa of 2006 began the study of a larger class of quaternionic functions, which includes all right quaternionic polynomials. These functions, now called *slice regular*, turned out to have zero sets with analogous properties. At later stages, the theory of slice regular functions has been generalized to other algebras: the Clifford algebra $\mathbb{R}_3$ (Gentili, Struppa, 2008), all Clifford algebras $\mathbb{R}_n$ (Colombo, Sabadini, Struppa, 2009), the algebra of octonions (Gentili, Struppa, 2010), all alternative *-algebras (Ghiloni, Perotti, 2011). Recent developments in the theory of slice regular functions over alternative *-algebras exposed new phenomena concerning the zeros sets of such functions and, in particular, of polynomials. The talk will provide examples of these phenomena and, time permitting, put them into context with the statement of general results. This is part of a joint work with Riccardo Ghiloni and Alessandro Perotti.

20 Graça Tomaz: Matrix representation of real and hypercomplex Appell polynomials

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In [1] a unified approach to the matrix representation of different types of real Appell polynomials was developed, based on a special matrix which has only the natural numbers as entries. This matrix, also called *creation matrix*, generates the Pascal matrix and allows to consider a set of Appell polynomials as solution of a first order vector differential equation with certain initial conditions. Besides a new elementary construction of the monogenic exponential function studied in [2], we analogously derive examples of different sets of *non-homogenous* hypercomplex Appell polynomials given by its matrix representation.

References

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21 José G. Vargas: Total operators and Inhomogeneous proper-value equations: quarks

José G. Vargas
PST Associates, LLC, USA

Dedicated to Professors Eckhard Hitzer, Zbigniew Oziewicz and Wolfgang Sprößig

Kähler's two-sided angular momentum operator, $K+1$, is neither vector-valued nor bivector-valued, but is total in the sense that it involves terms for all three dimensions. Proper functions of its components are not proper functions of $K+1$, but satisfy "inhomogeneous proper-value equations", i.e. of the form $(K+1)U = \mu U + \pi$, where π is a scalar that we name co-value. We consider one such equation for operators T comprising $K+1$ as a factor, other factors being for space and spacetime translations. We study the action of those T's on linear combinations of constant idempotents, so that only the algebraic (spin) part of $K+1$ has to be considered. π is now, in general, a non-scalar member of a Kähler algebra. We develop the system of equations to be satisfied by the combinations that make π a scalar. We solve for its solutions with $\mu = 0$, which actually also makes $\pi = 0$.
The solutions with $\mu = \pi = 0$ have all three constituent parts, 36 of them being different in the ensemble of all such solutions. That set of different constituents is structured in such a way that we might as well be speaking of an algebraic representation of quarks. In this paper, however, we refrain from pursuing this identification in order to emphasize the purely mathematical nature of the argument.

22 Iuliia Vasil'eva: Method of hypergeometric function in the problem of an interface crack with a rigid patch plate on part of its edge

Iuliia Vasil'eva
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Plane and antiplane stress state of a piecewise-homogeneous elastic body with a semi-infinite crack along the interface is considered. A rigid patch plate is attached to one of the crack edges on a finite interval adjacent to the crack tip. The crack edges are loaded with specified stresses. The body is stretched at infinity by specified stresses. External forces with a given principal vector and moment act on the patch plate. The problem reduces to a Riemann-Hilbert boundary-value matrix problem with a piecewise-constant coefficient for two complex potentials in the plane case and for one in the antiplane case. The complex potentials are found explicitly using a Gaussian hypergeometric function. The stress state of the body close to the ends of the patch plate, one of which is also simultaneously the crack tip, is investigated. Stress intensity factors near the singular points are determined.

References

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Acknowledgments: This research is supported by the German Academic Exchange Service (DAAD).

23 Fabio Vlacci: On a decomposition of some subgroups of quaternionic transformations

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Instituto de Matemáticas, Unidad Cuernavaca,
Fabio Vlacci
University of Florence, Italy

In this talk we'll present some results concerning decompositions of some subgroups of quaternionic transformations which were recently applied in the paper [1]. In particular we'll focus our attention to invertible fractional transformation which preserves the one dimensional quaternionic hyperbolic space and will extend to this groups the analog of Iwasawa decomposition as in the compleex case.

References

[1] Díaz, J. P., Verjovski, A.,Vlacci, F.: *Quaternionic Kleinian Modular Groups and Arithmentic Hyperbolic Orbifolds over the Quaternions*, `arXiv: 1503.07214`.

Further participants:

Hennie De Schepper, Ghent,
Martin Isoz, Prague,
Drahoslava Janovská, Prague,
Reiner Lauterbach, Hamburg,
Gerhard Opfer, Hamburg,
Wolfgang Sprößig, Freiberg.

24 Schedule of conference

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Monday, June 15, 2015
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12.30 to 14.00: Lunch break
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19.30 to 20.00: Schmeikal(17)

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12.30 to 14.00: Lunch break
14.00 to 15.30: Schneider(18), Bock(4), Malonek(12)
15.30 to 16.00: Coffee break and end of conference

25 Imprint

Organizers of the meeting:
Drahoslava Janovská, Institute of Chemical Technology, Prague,
Gerhard Opfer, University of Hamburg,
Wolfgang Sprößig, TU Bergakademie Freiberg.

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`http://ncaa.vscht.cz/`
Vladimír Janovský, jr.