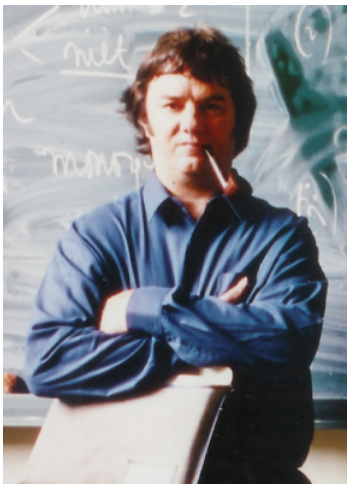

PAST AND FUTURE DIRECTIONS IN HYPERCOMPLEX AND HARMONIC ANALYSIS

Celebrating Frank Sommen's 60th birthday

Booklet of Abstracts

AVEIRO

March 29-April 02, 2016

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GENERAL INFORMATIONS

WELCOME

We welcome you all to the International Conference Past and Future Directions in Hypercomplex and Harmonic Analysis. The conference will take place at the room Sousa Pinto (second floor). As we celebrate Frank Sommen's 60th birthday and his fundamental contributions to the field of higher-dimensional function theories, in particular Clifford analysis, and their applications to mathematical physics, signal and image processing, operator theory, this conference is the perfect occasion to celebrate the event among long time friends and collaborators.

INTERNET ACCESS

Rooms are available for checking your e-mail trough a computer terminal

Login: s.conference@visit.uaveiro.eu

The password will be indicated upon arrival. **Important:** please, do not change the password, as it is a multiple login.

Alternatively, if you possess a personal Laptop with WLAN you can use either the above login or your personal EDUROAM access at your home university.

COMPUTER TERMINALS

Computers terminal are available at the room 11.2.7, located in the 2nd floor. However, due to lecturing restrictions, please do confirm its availability before entering (schedule is fixated at the door).

WHERE TO EAT?

Around the campus there exist several coffee bars where you can have also small meals such as sandwiches, snacks, fruits, ice creams, etc.

For lunch or dinner, there exist several possibilities, listed below:

- **Refeitório de Santiago**, Monday to Friday, lunch 12h to 14h30 / dinner 18h30 to 20h30, Saturday and Sunday, lunch 13h to 14h30 / dinner 19h to 20h30.

  Prices: meat, fish, or vegetarian meals from 2,50 to 5,00 euros.

- **Edifício do Snack-bar and Self-Service (ground floor, meals: meat, fish, vegetarian)**, Monday to Friday, lunch 12h to 14h30.

  Prices: meat, fish, or vegetarian meals from 2,50 to 5,00 euros.

- **Restaurante Universitário (1st floor)**, Monday to Friday, lunch 12h to 14h30.

  Prices: buffet service 7,00 euros

In addition, several restaurants can be found all around the campus.

CONFERENCE DINNER

Conference Dinner is planned on Tuesday, March 29, 2016, at 19:30, in the Best Western Hotel Imperial

URL: http://www.hotelimperial.pt/en/

The price for the Conference Dinner is 18,80 Euros per person, and it includes

Entrance

Smoked Ham with Melon

Main Course

Red Snapper in Oven with Bacon / Stuffed Veal

/ Sorted Vegetables with Olive Oil and Garlic (veg.)

Dessert

Sweet / Fruit

Tea or Coffee

SUPPORT

These events are supported by CIDMA, the Department of Mathematics of the University of Aveiro, and the FCT - Portuguese Foundation for Science and Technology within project UID/MAT/04106/2013 from the Portuguese side and by Dipartimento di Matematica, Politecnico di Milano, from the Italian side.

We wish you all a happy stay and a good and fruitful conference.

Aveiro, March 21, 2016

The Organizers

Paula Cerejeiras
Uwe Kähler

Fabrizio Colombo
Irene Sabadini

ABSTRACTS

29th March

10:00 *Registration*

10:15 *Opening Session*

10:30-12:05 Laudatio

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12:15-14:30 *Lunch*

14:30-15:00 On the inversion of the Fueter mapping theorem

Irene Sabadini
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In this talk we discuss the inversion of the Fueter mapping theorem for axially monogenic functions of degree k. Every monogenic function on an axially symmetric open set U can be written as a series of axially monogenic functions of degree k, i.e. functions of type $\breve{f}_k(x) := [A(x_0,\rho) + \underline{\omega}B(x_0,\rho)]\mathcal{P}_k(\underline{x})$, where $A(x_0,\rho)$ and $B(x_0,\rho)$ satisfy a suitable Vekua-type system and $\mathcal{P}_k(\underline{x})$ is a homogeneous monogenic polynomial of degree k. The Fueter mapping theorem says that given a holomorphic function f of a paravector variable defined on U then the function $\breve{f}(x)\mathcal{P}_k(\underline{x})$ given by

$$\Delta^{k+\frac{n-1}{2}}(f(x)\mathcal{P}_k(\underline{x})) = \breve{f}(x)\mathcal{P}_k(\underline{x})$$

is a monogenic function. The inversion of the Fueter mapping theorem consists in determining a holomorphic function f of a paravector variable when $\breve{f}(x)\mathcal{P}_k(\underline{x})$ is given. This result allows to

invert the Fueter mapping theorem for any monogenic function defined on an axially symmetric open set. If time permits we shall consider the inverse Fueter mapping theorem for biaxially monogenic functions.

This is a joint work with F. Colombo and F. Sommen.

15:05-15:35 The Fourier Multiplier Method for Inversion of the Fueter Theorem for Even Dimensions

Qian Tao
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In this joint talk with B. Dong, A. Kou, I. Sabadini we will show that the inversion of the Fueter theorem and its generalizations to $\mathbb{R}^{n+1}$ holds for all positive integers n. The result is proved via the Fourier multiplier method. For n being odd integers the result coincides with the existing one by Colombo, Sabadini, Sommen proved through the pointwise differential operator, viz., the integer power of the Laplacian.

15:40-16:10 FFT

Fred Brackx
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This talk is about a problem for the delta distribution in spherical co-ordinates.

16:15-16:45 *Coffee-break*

16:45-17:15 Frank Sommen, Integral Geometry and Aveiro

Uwe Kähler
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17:20-17:50 A generalized Fourier transform based on the Vahlen group

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The Fourier transform is an important tool in theoretical and applied analysis to analyze functions or signals. There had been made different approaches to generalize the Fourier transform in the context of Clifford analysis. These generalizations focused on the monogenic extension of the kernel of the Fourier transform or the geometric property of $i^2 = -1$.

Our approach is based on the canonical linear transform which puts the Fourier transform in the context of a general class of transformations which are related to groups. These class of integral transforms constitutes a parametrized continuum of transforms which include not only the Fourier transform but also Laplace, Gauß-Weierstraß and Bargmann transforms as special cases. The theory was developed by K. Wolf in a couple of papers and has been generalized to the general symplectic group by M. Gosson. Our approach focuses on unit quaternions which form the compact symplectic group $Sp(1)$ and the special Vahlen group of Clifford algebras.

We identify the special Vahlen matrix $V = \begin{pmatrix} a & b \\ c & d \end{pmatrix}$, where a, b, c, $d \in \Gamma_n$ (Clifford group) and fulfill the properties of the special Vahlen group with the generating function

$$W(x,y) = \tfrac{1}{2} d\, b^{-1}(x \cdot x) - b^{-1}\,(x \cdot y) + \tfrac{1}{2} b^{-1} a\,(y \cdot y)$$

and the transform

$$\mathcal{F}_V(f)(x) := \int_{\mathbb{R}^n} \exp(iW(x,y))\, f(y)\, dy.$$

17:55-18:25 Number sequences in terms of Clifford algebra generators: On generalized Vietoris' number sequences by using nD-Appell polynomials

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As is well known, certain number sequences reveal connections between different subjects from seemingly very distant mathematical areas like, for example, harmonic analysis and number theory. Recently, the relationship of a celebrated theorem of L. Vietoris (1958) about the positivity of certain sine and cosine sums with the function theoretic concept of stable holomorphic functions in the unit disc has been shown by Ruscheweyh and Salinas (2004). Already on several earlier occasions, R. Askey (1974, 1975, 1998) stressed the role of that theorem in the theory of orthogonal

polynomials and special functions. Nevertheless, so far, the coefficient sequence which plays the crucial role in Vietoris' theorem has not been the object of a deeper analysis by its own.

Our observation that this sequence is identical to the number sequence that characterizes a generalized 3D-Appell sequence of Clifford holomorphic polynomials sheds new light on its properties. Moreover, its generalizations are naturally obtained through the application of nD-Appell polynomials. Furthermore and rather unexpected, the application of several hypercomplex variables allows their representation exclusively by means of the non-commutative Clifford algebras generators.

Joint work with I. Cação, and M. I. Falcão.

19:30 *Dinner at the Best Western Hotel Imperial*

30th March

10:30-11:00 Some aspects of noncommutative phase space analysis

Michael Ruzhansky
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In this talk we will give some ideas of the resent research on some aspects of the noncommutative phase space analysis.

11:05-11:35 On algebras which are inductive limits of Banach spaces

Daniel Alpay
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In the talk, we introduce algebras which are inductive limits of Banach spaces and carry inequalities which are counterparts of the inequality for the norm in a Banach algebra. We then define an associated Wiener algebra, and prove the corresponding version of Wiener theorem. Finally, we consider factorization theory in these algebra, and in particular, in the associated Wiener algebra. Applications to infinite dimensional analysis and free processes will be outlined.

The talk is based on works with David Levanony, Palle Jorgensen and Guy Salomon.

11:40-12:10 Parabolic Curvelet Transform

Thomas Fink
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In this talk we will sketch the idea of an edge detection method which allows a simultaneous estimation of the edges curvature. To this end, we will expand the concept of the classical Wavefront Set, which indicates the position and direction of a singularity, to also include its local curvature. On this basis we will introduce the Parabolic Curvelet Transform and show its connection to the expansion of the Wavefront Set.

12:15-14:30 *Lunch-break*

14:30-15:00 Fundamental solutions of the multi-dimensional time-fractional heat and wave equations and related parabolic Dirac operators

Milton Ferreira
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In this talk we present explicit formulas for the fundamental solution of the multi-dimensional time-fractional heat and wave equations and related parabolic Dirac operators. In these operators we replace the first-order time derivative by the Caputo fractional derivative of order $\beta \in]0, 2]$. Applying operational techniques via the multi-dimensional Fourier transform and the Mellin transform we write the fundamental solution as a Mellin-Barnes integral. This integral is then evaluated using the Residue Theorem and taking into account the parity of the dimension. The fundamental solution can be rewritten using Wright and Fox-Wright functions. From the obtained fundamental solution we deduce the fundamental solution of the time-fractional parabolic Dirac operator, which factorizes the time-fractional heat and wave operators. To illustrate our results we present some plots of the fundamental solution for some particular values of the fractional parameter.

This is a joint work with N. Vieira.

15:05-15:35 Fischer decomposition in generalized fractional Clifford analysis, the ternary case

Mihaela Vajiac
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We will describe the generalized fractional Clifford analysis in dimension 3, namely analysis on the "ternary" Clifford algebras. We will give a complete description of the spaces of monogenic functions in this sense and find a basis of the space of fractional homogeneous monogenic polynomials.

15:40-16:10 Eigenfunctions and Fundamental Solutions of the Fractional Laplace and Dirac operators

Nelson Felipe Vieira
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In the last decades the interest in fractional calculus increased substantially. Among all the subjects there is a considerable interest in the study of ordinary and partial fractional differential equations regarding the mathematical aspects and methods of their solutions and their applications in diverse areas such as physics, chemistry, engineering, optics or quantum mechanics.

The aim of this talk is to present, by application of two methods, a closed formula for the family of eigenfunctions and fundamental solutions of the three-parameter fractional Laplace operator using Riemann-Liouville fractional derivatives, as well as, a family of fundamental solutions of the associated fractional Dirac operator.

The first approach corresponds to an application of operational techniques via the Laplace transform associated to the extension of the Laplace transform to generalized functions. With this operational approach we can describe a complete family of eigenfunctions and fundamental solutions in classes of functions represented by the left-sided fractional integral of a L_1-function. In the second approach we consider the classical method of separation of variables. In both approaches the obtained solutions are expressed in terms of Mittag-Leffler functions.

Since there is a duality relation between Caputo and Riemann-Liouville fractional derivatives, we present the analogous of the presented results for the case where Caputo fractional derivatives are used. Moreover, we present some graphical representations of the solutions obtained via separation of variables for some values of the fractional parameter.

This is a joint work with M. Ferreira.

16:15-16:45 *Coffee-break*

16:45-17:15 The $\mathbb{Z}_2^n$ Dirac-Dunkl operator and a higher rank Bannai-Ito algebra

Hendrik De Bie
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The kernel of the $\mathbb{Z}_2^n$ Dirac-Dunkl operator is examined. The symmetry algebra A_n of the associated Dirac-Dunkl equation is determined and is seen to correspond to a higher rank generalization of the Bannai-Ito algebra. A basis for the polynomial null-solutions of the Dirac-Dunkl operator is constructed. The basis elements are joint eigenfunctions of a maximal commutative subalgebra of A_n and are given explicitly in terms of Jacobi polynomials. The symmetry algebra is shown to act irreducibly on this basis via raising/lowering operators. A scalar realization of A_n is proposed.

This is joint work with V. Genest and L. Vinet.

17:20-17:50 Some estimates for the dimension of the kernel of a singular integral operator with non-Carleman shift and conjugation

Rui Marreiros
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On the Hilbert space $\widetilde{L}_2(\mathbb{T})$ the singular integral operator with non-Carleman shift and conjugation $K = P_+ + (aI + AC)P_-$ is considered, where $P_\pm$ are the Cauchy projectors, $A = \sum\limits_{j=0}^{m} a_j U^j$, a, a_j, $j = \overline{1, m}$, are continuous functions on the unit circle $\mathbb{T}$, U is the shift operator and C is the operator of complex conjugation. Some estimates for the dimension of the kernel of the operator K are obtained.

This talk is based on a joint work with Ana Conceição.

17:55-18:25 On the trace of the self-commutator of Poly-Toeplitz operators with analytic symbols

Luís V. Pessoa
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The trace of the self-commutator of the Bergman Toeplitz operator with analytic symbol has been computed by different techniques. Some of them follows from the famous theorem of Berger-Shaw for multicyclic hyponormal operators. Simply the mentioned self-commutator lies in the trace class iff the Dirichlet integral of its symbol is finite, in which case the later integral gives the trace of the self-commutator. We will begin by present a short history concerning the membership in the trace class and more generally in the Schatten classes of the self-commutator of the Bergman Toeplitz with analytic symbol. The Bergman Poly-Toeplitz operator is defined to be the natural Toeplitz operator acting on the poly-Bergman space. The study of the trace of the self-commutator of Poly-Toeplitz operators with analytic symbol began quite recently. With the help of the Berger-Shaw theorem, we will discuss the membership in the trace class of this self-commutator on bounded domains. In the unit disk case we will show that it lies in the trace class iff the Bergman Toeplitz operator is a trace class operator and that its trace is proportional to the order of polyanalyticity of the poly-Bergman space in play. We will also notice that the trace of the self-commutator of the poly-Toeplitz operator acting in the j poly-Bergman space and of the Bergman Toeplitz operator acting on an invariant subspace with the co-dimension j property, coincide, according to ours trace formula and that of *K. Zhu*, respectively.

31st March

10:30-11:00 Berezin transforms attached to Landau levels

Zouhaïr Mouayn
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We review the definition and properties of coherent states with examples. We construct coherent states attached to Landau levels on the Poincaré disk $\mathbb{D}$, Euclidean plane $\mathbb{C}$ and the Riemann sphere $\mathbb{CP}^1$. Generalization to the complex unit ball $\mathbb{B}^n$, to $\mathbb{C}^n$ and $\mathbb{CP}^n$ are also discussed. In these cases, we apply a coherent states quantization method to recover the corresponding Berezin transforms and we give formulae representing these transforms as functions of Laplace-Beltrami operators.

11:05-11:35 Operators on compact groups

Jens Wirth
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In this talk we will present some recent results on the global symbolic calculus of operators on compact Lie groups. Operators on compact Lie groups are described in terms of global symbols, which are matrix-valued functions on the non-commutative phase space $G \times \widehat{G}$, where G denotes the compact Lie group under consideration and $\widehat{G}$ the set of equivalence classes of irreducible unitary representations of the group G. Symbol classes for operators are characterised in terms of differential-difference conditions.

We will focus on the particular example of the 3-sphere $\mathbb{S}^3$, understood as set of unit quaternions, and show how the differential-difference calculus arises in a natural way when considering spaces of homogeneous polynomial as the representation spaces. We will give explicit formulas and recurrence relations and explain central parts of the associated calculus. Applications involve differential operators, the Szegő projector and projections associated to the 2-sphere as homogeneous space of $\mathbb{S}^3$.

11:40-12:10 Real and (Hyper)Complex Techniques in Harmonic Analysis

`Vladimir Kisil`
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The theory of a complex variable has intimate connections with the harmonic analysis. It was pretty obvious from the beginning that several complex variables cannot serve a similar role to the theory of harmonic functions in many dimensions. E. Stein and his school developed real variable technique to fill the gap. It was primary based on the Hardy-Littlewood maximal functions. Clifford analysis, which flourished a bit later, provides the right path to treat harmonic functions in the spirit of complex variables. Presently, there is a certain rivalry between the real variable methods and Clifford techniques.

We give a unified presentation of both approaches based on the group of affine transformation. Then, concepts from two fields are lined up in two parallel chains with, say, the maximal function corresponding to the Cauchy integral formula. This opens an opportunity of fruitful co-operation between two techniques with mutual enrichment.

12:15-14:30 *Lunch-break*

14:30-15:00 Script geometry: geometry based on a boundary operator

Adrian Vajiac
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In this paper we show how the notion of a boundary operator can be used to generate geometry. We start with a set of points, then we add lines as elements that connect two points and then plane cells are defined as elements that are bounded by polygons and so on. The definition of the boundary operators however does not require the use of the idea of endpoints or polygons since these notions follow from a more general tightness condition. We also define a coboundary operator and a Hodge-Dirac operator for scripts. We work out several examples of scripts including a Moebius band, a torus, a Klein bottle and several versions of the projective plane and we compute the corresponding homology, cohomology and spectrum of the Dirac operator.

15:05-15:35 Symmetries of the discrete Dirac operator: rotations and translations

Hilde De Ridder
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We consider the discrete 'split' Clifford analysis setting, a function-theory in higher dimensions studying discrete functions on the grid $\mathbb{Z}^m$. The discrete Dirac operator ∂, which is defined by means of both forward and backward difference operators $\Delta_j^{\pm} f(x) = \pm\,(f(x \pm e_j) - f(x))$ combined with forward and backward basis elements $\boldsymbol{e}_j^{\pm}$, factorizes the star Laplacian ($\partial^2 = \Delta^*$). The forward and backward basis elements sum up to the standard basis element e_j of Euclidean Clifford analysis. The function theory is centered around the notion of discrete monogenic function, i.e. null-functions of ∂. It is in this setting that we will discuss the introduction of discrete rotations and discrete translations from a representation-theoretical point of view: the infinitesimal generators of the rotations, $L_{a,b} = R_a\, R_b\, (\xi_a\, \partial_b + \xi_a\, \partial_b)$, $a \neq b$ respectively $L_{a,b} - \frac{1}{2}\, R_a\, R_b$, are symmetries of the discrete Laplace resp. Dirac operator that allow us to express the space $\mathcal{H}_k$ resp. $\mathcal{M}_k$ of discrete harmonic resp. monogenic k-homogeneous polynomials as reducible $\mathfrak{so}(m, \mathbb{C})$-representations. We will briefly discuss the decomposition in irreducible representations by means of suitable idempotents. The infinitesimal generators of the discrete translations are defined as symmetries of the Dirac operator that satisfy the same commutator-relations with the generators of the discrete rotations as their classical counterparts do. We will try to keep the details to a minimum and give an overview of the motivation, difficulties and a few examples rather than go into details.

15:40-16:10 Post-Modern Topics in Discrete Clifford Analysis

Nelson Faustino
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In this talk I will speak about some developments obtained during the persecution of the project entitled *Applications of discrete Clifford calculus in field theories* (13/07590-8), funded by the *São Paulo Research Foundation* (FAPESP). Namely about:

1. The role of symmetries in the construction of special functions of hypercomplex variable on the lattice.
2. Further applications in discrete quantum mechanics and relativistic wave mechanics.
3. Limitations and gaps inherit to the extension of families of symmetries of Weyl-Heisenberg type.
4. New proposals using Bayesian probabilities and conformal group structures.

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16:15-16:55 *Coffee-break and Poster Session*

16:55-17:25 Arbitrary Order Fermionic and Bosonic Operators: Conformally Invariant Higher Spin Operators

John Ryan
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We discuss joint work with Chao Ding and Raymond Walter that considers extensions of earlier work on conformal invariance and powers of the Dirac operator to the higher spin setting. The higher spin theory emerged most notably when Bures et al. introduced the Rarita-Schwinger operators on function spaces of k-homogeneous monogenic polynomials. We begin by constructing the Rarita-Schwinger operators according to the representation-theoretic method of Stein and Weiss, and use Stokes Theorem to correct an earlier proof of its conformal invariance. We proceed to consider the (non-constructive) classification scheme of Slovak and Soucek for higher spin operators, based on representation theory. Eelbode and Roels followed by De Bie et al. explicitly constructed the Maxwell operator and higher spin Laplace operators, providing the second-order conformally invariant operators on spaces of k-homogeneous harmonic polynomials. This used the method of generalized symmetries. We used this same method to construct arbitrary order conformally invariant operators of lower spin. Related work constructed the third and fourth order operators of arbitrary spin. Inspired by mathematical physics, we introduce the terminology of fermionic (resp. bosonic) operators for odd order, half-integer spin (even order, integer spin) conformally invariant operators. We present a computationally tractable, explicit construction of general bosonic and fermionic operators. This approach is based on finding operators with the correct fundamental solutions for these conformally invariant operators. Thus conformal invariance and fundamental solutions naturally emerge in our framework.

17:30-18:00 On some boundary value problems for the p-Dirac equation

Klaus Gürlebeck, Z. Al-Yasiri
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We consider boundary value problems for the p-Laplace equation and transfer them by using quaternionic analysis to boundary value problems for a p-Dirac equation. These problems will be solved iteratively by applying a fixed-point principle. Finally, we discuss the numerical solution by

applying a discrete function theory. Numerical results will be presented showing advantages and problems of this approach.

18:05-18:25 The Fueter mapping theorem and the Riesz projectors of the F-functional calculus

Jonathan Gantner
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The Fueter mapping theorem is one of the deepest results in hypercomplex analysis. It was introduced by R. Fueter for the quaternions and later generalized by M. Sce and T. Qian to the Clifford algebra setting. It admits an integral representation, introduced by F. Colombo, I. Sabadini and F. Sommen, which allows to define the so called F-functional calculus. Based on the two possible formulations of the Fueter mapping theorem in integral form, there are the two formulations of the F-functional calculus.

The F-resolvent operators of this calculus are related to the commutative version of the S-spectrum of a quaternionic operator. The two formulations of the F-functional calculus and the F-resolvent equation are of crucial importance to study the analogue of the Riesz projectors in this setting.

18:30-18:50 Rational approximation of functions in the Hardy spaces on tubes

Mai Wei-Xiong
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We study rational function approximation in several complex variables. The study is based on the Hardy space theory on tubes over cones. As application it gives rise to L^2 approximation to functions of several real variables.

1st April

10:05-10:25 Uncertainty Principle and Phase-Amplitude Analysis of Signals on Spheres and Euclidean Spaces

Dang Pei
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This talk is devoted to studying uncertainty principles of Heisenberg type for signals in two settings. One is defined on $\mathbf{R}^n$ taking values in a Clifford algebra, and the other one is on the unit sphere in both the Clifford algebra and the vector space settings. In both of two settings, we obtain two uncertainty principles of which both correspond to the strongest form of the Heisenberg type uncertainty principles for the one-dimensional space. The lower-bounds of the new uncertainty principles are in terms of a scalar-valued phase derivative.

10:30-11:00 Iterated Integral Representations

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The Cauchy-Pompeiu formula for complex C^1-functions in regular plane domains provides the basic integral representation in complex analysis. It is an adequate modification of the Gauss divergence theorem which is the main theorem of calculus in higher dimensions. Imitating the iteration process of developing the Taylor formula in $\mathbb{R}$ leads to higher order integral representations. But for complex functions there are two partial differential operators, the Cauchy-Riemann and its complex conjugate operator. Hence there are mainly two different ways of iterating, leading to representation formulas related to the bianalytic (Bitsadze) and the harmonic (Laplace) differential operators. But these formulas appear as improper as they are not adjusted to any well-posed boundary value problems. This fact is known already from the Cauchy-Pompeiu formula where the Schwarz is a proper modification of the Cauchy kernel. Adjusting the fundamental solutions of the bianalytic and the harmonic operator properly leads to bianalytic Schwarz kernels and to harmonic Green and Neumann and more general Robin functions. While the concepts of these kernel functions are obvious, to find explicit expressions for them is only for particular domains possible. Some examples are given attained by the parqueting-reflection principle for certain domains the boundaries of which are composed by arcs from circles and lines.

Further iterations lead to higher order polyanalytic Schwarz kernels and to hybrid polyharmonic Green functions, but also to combinations of kernel functions of Schwarz and Green kind related to products of polyanalytic and polyharmonic differential operators. This latter process is involved and opens a wide field for research. Even the iteration of just Green functions itself for the unit disc is not complete. In some theses at FU Berlin iterated polyharmonic Green functions are calculated up to order 4. But the polyharmonic Poisson kernels, the normal derivatives of the iterated polyharmonic Green function, of any order is found for the disc and the half plane.

11:05-11:35 On some properties of integral operators and its relation with the Cimmino system of partial differential equations

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In this talk we will give brief survey of integral operators, which have been done in theory of Cimmino system and very recent developments in this theory.

The talk is based on joint works with R. Abreu Blaya, J. Bory Reyes, A. Guzmán Adán and Luis M. H. Simon.

11:40-12:10 Quaternionic Functions and their Applications in Mechanics of Continua

Yuri Grigor'ev
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We used a quaternion function method for the Moisil-Theodorescu system (MTS) [1, 2]. Solutions of the MTS are (left-) regular quaternion functions $f(\mathbf{r}) = f_0(\mathbf{r}) + \mathbf{f}(\mathbf{r}) = f_0(x,y,z) + \mathbf{i}f_x(x,y,z) + \mathbf{j}f_y(x,y,z) + \mathbf{r}f_z(x,y,z)$ of a reduced quaternion variable $\mathbf{r} = \mathbf{i}x + \mathbf{j}y + \mathbf{k}z$. In [3, 4] some results have been presented by using of a radial integration method in star-shaped regions. Here we present the generalized Kolosov-Muskhelishvili formulae in arbitrary not only star-shaped domains:

$$2\mu\mathbf{u}(\mathbf{r}) = \varkappa\Phi(\mathbf{r}) + \overline{\mathbf{r}\varphi(\mathbf{r})} - \overline{\psi(\mathbf{r})},\ \varkappa = 8\nu - 7,\ \Phi = \nabla\varphi,\ \varkappa\Phi_0 = \mathbf{r}\cdot\boldsymbol{\varphi} + \psi_0,$$

where a notion of primitive function is used different from [5]. It is shown that in particular cases of plane and axially symmetric deformations this representation goes into the Kolosov-Muskhelishvili

and Solovyov formulae. An analogical quaternionic representation is obtained for the Stokes system of hydrodynamics. A foundation of such results is a new method of reconstruction of a regular function from a given scalar part.

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12:15-14:30 *Lunch-break*

14:30-15:00 Modified spherical harmonics

Heinz Leutwiler
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A modification of the classical theory of spherical harmonics is presented. The unit sphere S in $\mathbb{R}^3 = \{(x, y, t)\}$ is replaced by the half-sphere S_+ in the upper half space, the Euclidean scalar product on S by a non-Euclidean one on S_+, and the Laplace equation $\Delta h = 0$ by the equation $t\Delta v + \frac{\partial v}{\partial t} = 0$. It will be shown that most results from the theory of spherical harmonics in $\mathbb{R}^3$ stay valid in this modified setting.

15:05-15:35 Hyperbolic Harmonic Functions and their Functions Theory

Sirkka-Liisa Eriksson
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There is a rich interplay between potential theory and complex function theory in the plane. In higher dimensions similar interplay between potential theory of harmonic functions and the function theory of Euclidean Dirac operator exists and is pretty well investigated. A generalization of harmonic functions on manifolds is defined by the Laplace-Beltrami operator. One of interesting manifolds is defined by the hyperbolic metric. Leutwiler noticed around 1990 that if the usual Euclidean metric is changed to a hyperbolic one on the upper half space model then the power function, calculated using Clifford algebra, is a solution of the hyperbolic Dirac equation. We present some recent developments of hyperbolic function theory.

15:40-16:10 The Dirichlet Problem for the λ-Laplacian in an Annular Region

Craig A. Nolder
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The λ-Laplacian is a Weinstein equation which in special cases reduces to the usual Laplacian and the invariant Laplacian. We solve this equation in an annular region in space. This requires using hypergeometric functions in the radial extensions. This solution has been known for the usual Laplacian but seems to be new in the interesting case of the invariant Laplacian.

16:15-16:45 *Coffee-break*

16:45-17:15 Some special functions in real and complex Clifford analysis

Dixan Peña-Peña
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The Cauchy-Kowalevski extension and Fueter theorems are basic results in Clifford analysis. In this talk we shall present some special functions which are closely related to these two theorems.

17:20-17:50 On hyperbolic equation systems

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In this talk we consider hyperbolic equation systems. They are systems related to the hyperbolic function theory (Leutwiler, Eriksson) or classical many variable Clifford (super) analysis (Sommen et. al.).

17:55-18:15 Integral representation formula for Multi Meta$-\varphi-$monogenic functions

Antonio Di Teodoro
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Consider the following operator

$$\mathcal{D}_{\varphi^{(j)},\lambda^{(j)}} = \varphi_0^{(j)}\partial_{x_0^{(j)}} + \sum_{i=1}^{m_j} \varphi_i^{(j)}(x) e_{i+a_j}\partial_{i+a_j} - \lambda^{(j)}$$

where $\varphi^{(j)}$ is a Clifford$-$valued function and $\lambda^{(j)}$ is a Clifford$-$constant defined by

$$\varphi^{(j)} = \varphi_0^{(j)} + \sum_{i=1}^{m_j} \varphi_i^{(j)} e_{i+a_j}, \quad \lambda^{(j)} = \lambda_0^{(j)} + \sum_{i=1}^{m_j} \lambda_i^{(j)} e_{i+a_j}$$

with $m = m_1 + \cdots + m_n$, $a_1 = m_0 = 0$ and $a_j = m_1 + \cdots + m_{j-1}$ for $j = 2, \ldots, n$; and $\varphi_i^{(j)}$ can be real-valued functions defined in $\mathbb{R}^{m_1+1} \times \mathbb{R}^{m_2+1} \times \cdots \times \mathbb{R}^{m_n+1}$. $\lambda_i^{(j)}$ are real numbers for $i = 0, 1, \ldots, m_j$ and $j = 1, \ldots, n$.

A function u is Multi meta$-\varphi$-monogenic of second class, in several variables $x^{(j)}$, for $j = 1, \ldots, n$, if

$$\mathcal{D}_{\varphi^{(j)},\lambda^{(j)}} u = 0.$$

In this talk we give a Cauchy-type integral formula for Multi meta$-\varphi-$ monogenic of second class operator in one way by iteration and in the second way by the use of the construction of the Levi function.

Joint work with Eusebio Ariza.

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18:20-18:40 On Modified Quaternionic Analysis, Cubic Irrotational Vector Fields and Qualitative Theory of Kolmogorov Equations in $\mathbb{R}^3$

Dmitry Bryukhov
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In 2014 the author demonstrated surprising applications of modified quaternionic analysis in $\mathbb{R}^3$ for research of axially symmetric cubic gradient dynamical systems with variable dissipation in the form of ecological, or Kolmogorov equations. Quadratic and cubic reduced quaternionic polynomials with real coefficients in the framework of Fueters construction were considered at the first stage. Now role of reduced quaternionic polynomials with complex coefficients in our approach is described. Geometric properties of singular sets of corresponding generalizations of conformal mappings of the second kind in $\mathbb{R}^3$ are substantially different. Important hypothesis about the Jacobian matrix of generalizations of conformal mappings of the second kind in $\mathbb{R}^3$ in the framework of Fueters construction, published in 2014, is proved.

2nd April

10:00-10:30 How to use *Mathematica* to explore the spectra of some classes of singular integral operators

Ana C. Conceição
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Spectral theory has many applications in several main scientific research areas (Structural Mechanics, Aeronautics, Quantum Mechanics, Ecology, Probability Theory, Electrical Engineering, among others) and the importance of its study is globally acknowledged. In recent years, several software applications were made available to the general public with extensive capabilities of symbolic computation. These applications, known as computer algebra systems (CAS), allow to delegate to a computer all, or a significant part, of the symbolic calculations present in many mathematical algorithms.

The main goal of this talk is to present the spectral algorithm [ASpecPaired-Matrix] which use the symbolic and numeric computation capabilities of the CAS *Mathematica* to explore the spectra of some classes of singular integral operators with rational matrix functions coefficients, defined on the unit circle. This analytical algorithm allow us to check, for each considered paired singular integral operator, if a complex number (chosen arbitrarily) belongs to its spectrum. Some nontrivial examples are presented.

This talk is based on a joint work with José C. Pereira.

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10:35-11:05 Clifford algebra-valued orthogonal polynomial systems and some of their properties

Isabel Cação
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Clifford algebra-valued polynomial systems were constructed in the 80s of last century by several authors (R. Delanghe, F. Sommen, F. Brackx, ...). The concept of hypercomplex derivative of a monogenic function, given in 1999 by K. Guerlebeck et al., opened the way to the construction of Appell polynomial bases that are particularly suitable for approximating monogenic functions. Monogenic Appell polynomials were constructed by Malonek et al. in 2007 generalizing the classical definition of Appell polynomials of one real variable to Clifford analysis. Later, in 2012, R. Laviscka constructed complete orthogonal Appell systems of monogenic polynomials in arbitrary dimensions by using the notion of Gelfand-Tsetlin bases. In this talk, we study some properties satisfied by those systems, such as three-term recurrence relations and second order differential equation in a similar way to the orthogonal polynomials of one real variable. Moreover, we show that the process of construction of their building blocks relies only in the basic Appell sequence constructed by Malonek et al..

11:10-11:40 Numerical methods for computing the zeros of unilateral quaternionic polynomials

Irene Falcão
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The design of efficient methods for numerically approximating the zeros of real or complex functions can be considered as a central problem in scientific computation. The problem of finding the zeros of a quaternionic function is, as expected, more difficult than the root-finding problem in the complex plane. One can find in the literature important contributions to this subject, in particular in connection with the study of zeros of quaternionic polynomials. In fact, since the pioneering work of Niven in the 1940's, several algorithms have been proposed, but numerical methods based on quaternion arithmetic remain scarce. In this talk we revisit some of the available algorithms for quaternionic polynomial root-finding and present a direct approach based on the use of the so-called Factor Theorem for quaternions. This new iterative method shows fast convergence and robustness with respect to the initial approximations.

Joint work with F. Miranda, R. Severino, J. Soares.

11:45-12:05 Reproducing kernels of symplectic harmonics

Michael Wutzig
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On the space of harmonic polynomials of fixed homogeneity there exists a reproducing kernel that can be given by a Gegenbauer polynomial. In the even dimensional case one can apply a complex structure and consider bi-homogeneous harmonic polynomials. Here the reproducing kernel is described by means of a certain Jacobi polynomial. When the dimension is a multiple of four a second complex structure, i.e. a quaternionic structure, can be introduced which gives rise to so-called symplectic harmonics. In this talk we will derive the reproducing kernel in this setting and give the result explicitly.

12:15-14:30 *Lunch-break*

14:30-15:00 On the Fourier Expansion of k-holomorphic Cliffordian automorphic forms

Sören Kraußhar
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In this talk we look at the structure of the Fourier expansion of Clifford algebra valued functions that are solutions to $D\Delta^k f = 0$ where D is the Cauchy-Riemann operator, Δ the Laplacian and k some integer. In particular we study the Fourier coefficients of automorphic forms belonging to this function class and discuss their relation with objects from number theory.

15:05-15:35 Interpolation in hypercomplex analysis

Klaus Gürlebeck, Dmitrii Legatiuk
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This contribution presents an overview of available results related to the task of interpolation in hypercomplex setting. Especially, interpolation with monogenic functions will be discussed in detail. The recent results of interpolation with a special system of 3D monogenic polynomials with application to boundary value problems of linear elasticity will be presented.

15:40-16:00 Reconstruction of Quaternionic Signals with Sparsity Constrains

Narciso Gomes
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Compressed sensing is a new paradigm in signal processing which states that for certain matrices sparse representations can be obtained by a simple ℓ_1-minimization procedure. Here we explore this paradigm for higher-dimensional signals, in particular for quaternionic signals which represent color-encoded images such as RGB-images.

16:05-16:25 Radial algebra as an abstract framework for orthogonal and Hermitian Clifford analysis

Hennie De Schepper, Alí Guzmán Adán, Frank Sommen
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In this talk we discuss about the study of the algebra of endomorphisms defined on the so-called radial algebra, this is an algebra of abstract vectors variables which generalizes both polynomial and Clifford algebras. We will define, using different but equivalent approaches, the building blocks of an analysis on this abstract framework. These blocks are given by the abstract versions of the Dirac operator and the vector derivatives. By the study of these and other fundamental endomorphisms defined on the radial algebra setting we obtain an algebraic structure which can be considered as the abstract equivalent of the Hermitian Clifford analysis. Finally, we present some equivalent axiomatic definitions for the Hermitian radial algebra.

16:30-17:00 *Coffee-break and Closing Session*

POSTERS SESSION - 31st March

Poster 1 - A matrix approach in Quaternionic and Clifford-type Algebras

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In this poster, we are going to discuss a matrix approach to solve different problems in Clifford and Quaternionic analysis, such as: Necessary and sufficient conditions for associated operators, solution of initial and boundary value problems and others. As a consequence of this matrix approach, it is possible to create a package in Maxima, Mathematica or almost any other program to optimize the computation in the problems presented in Clifford and Quaternionic analysis.

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Poster 2 - Fractional Fischer decomposition

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In this work we present the basic tools of a fractional function theory in higher dimensions by means of a fractional correspondence to the Weyl relations via Gelfond-Leontiev operators of generalized differentiation. A Fischer decomposition is established. Furthermore, we give an algorithm for the construction of monogenic homogeneous polynomials of arbitrary degree.

Poster 3 - An introduction to quaternionic Gabor frames

Stefan Hartmann
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Gabor frames play a vital role not only in applied mathematics but also in modern harmonic analysis. This poster is going to present a non-trivial generalization of Gabor frames to the quaternionic case and give new density results.

Poster 4 - Towards a higher spin Fueter theorem

Tim Janssens
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When looking at the Laplace operator Δ_m on $\mathbb{R}^m$ one can, for each $k \in \mathbb{N}$, define the space

$$\mathcal{H}_k(\mathbb{R}^m, \mathbb{C}) := \mathcal{P}_k(\mathbb{R}^m, \mathbb{C}) \cap \ker \Delta_m$$

where $\mathcal{P}_k(\mathbb{R}^m, \mathbb{C})$ is the space of the k-homogeneous polynomials on $\mathbb{R}^m$. One can use the classic Fueter theorem to construct special harmonic polynomials starting from $\Re(z^{k+m-2})$ and these special polynomials are given in terms of Gegenbauer polynomials.
We will give a sketch of the approach we are taking to obtain a generalisation to the higher spin setting.

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TALKS & POSTERS - GLOBAL VISION

Hour	Tuesday, 29
10:00	Registration
10:15	Opening
10:30	R. Delanghe
11:20	W. Sprößig
12:15	Lunch
14:30	I. Sabadini
15:05	T. Qian
15:40	F. Brackx
16:15	Coffee-break
16:45	U. Kähler
17:20	S. Bernstein
17:55	H. Malonek
19:30	Dinner

Hour	Wednesday, 30
10:30	M. Ruzhansky
11:05	D. Alpay
11:40	T. Fink
12:15	Lunch
14:30	M. Ferreira
15:05	M. Vajiac
15:40	N. Vieira
16:15	Coffee-break
16:45	H. De Bie
17:20	R. Marreiros
17:55	L. Pessoa

Hour	Thursday, 31
10:30	Z. Mouayn
11:05	J. Wirth
11:40	V. Kisil
12:15	Lunch
14:30	A. Vajiac
15:05	H. De Ridder
15:40	N. Faustino
16:15	Coffee-break and Poster Session
16:55	J. Ryan
17:30	K. Gürlebeck
18:05	J. Gantner
18:30	W.-X. Mai

Hour	Friday, 01
10:05	D. Pei
10:30	H. Begehr
11:05	B. Schneider
11:40	Y. Grigor'ev
12:15	Lunch
14:30	H. Leutwiler
15:05	S-L. Eriksson
15:40	C. Nolder
16:15	Coffee-break
16:45	D. Peña-Peña
17:20	Heikki Orelma
17:55	A. Di Teodoro
18:20	D. Bryukhov

Hour	Saturday, 02
10:00	A. Conceição
10:35	I. Cação
11:10	I. Falcão
11:45	M. Wutzig
12:10	Lunch
14:30	S. Kraußhar
15:05	D. Legatiuk
15:40	N. Gomes
16:05	A. Adan
16:30	Coffee-break and Closing Session