Anno: 2016 - prot. BIRD167404

Richiesta di finanziamento per Progetto/Assegno di Ricerca

Assegno di Ricerca

1.0 Macroarea di Afferenza del Responsabile Scientifico del Programma di Ricerca
Principal Investigator's macroarea

1 - Matematica, scienze fisiche, dell'informazione e della comunicazione, ingegneria e scienze della Terra

1.1 Area Scientifica del Responsabile Scientifico del Programma di Ricerca
Principal Investigator's scientific area

01 - Scienze Matematiche

1.2 Responsabile Scientifico del Programma di Ricerca
Principal Investigator (PI)

DE MARCHI	Stefano	M
(Cognome/Surname)	(Nome/Name)	(sesso/gender)
PROFESSORE ASSOCIATO	MAT/08	17/12/1962
(Qualifica/Category)	(Settore Scientifico Disciplinare/ Scientific Disciplinary Sector)	(Data di Nascita/Date of Birth)
DMRSFN62T17B589H		DIP. MATEMATICA
(Codice fiscale/Tax code)		(Dipartimento/Department)
+39 0498271425	+39 0498271499	demarchi@math.unipd.it
(Prefisso e Telefono/ Code and Phone Number)	(Numero Fax)	(Indirizzo di Posta Elettronica/E-mail Address)

Lingua di compilazione del progetto
Language

English

1.3 Area Scientifica del Programma di Ricerca
Scientific area of the research program

Area Scientifica Prevalente /Main scientific Area	Scienze Matematiche	(% di afferenza) 80
Area Scientifica/Scientific Area	Scienze Mediche	(% di afferenza) 20
Area Scientifica/Scientific Area		(% di afferenza)

1.4 Titolo del Programma di Ricerca
Title

Radial basis functions approximations: stability issues and applications.

1.5 Abstract del Programma di Ricerca
Abstract

In kernel-based approximation among the variety of open problems, constructing stable bases for the associated native space is still a challanging problem. This problem has recently attracted the attention of many researchers, proposing often ad-hoc techniques (see for instance RBF-QR of [FLF11], RBF-Direct of [FMcC12]). Just to remind the most important it consists in finding the associated eigenfunctions (and the corresponding eigenvalues) of a compact self-adjoint integral operator (Mercer's theorem in Hilbert spaces).
In the recent work [DeMS13], it has been studied the so-called WSVD basis, which is strictly connected to the eigen-decomposition of this operator and allows to overcome some problems related to the stability of the computation of the approximant for a wide class of radial kernels (with infinite or finite smoothness). This basis turned out to be computationally expensive to compute. The problem has then been solved by resorting to methods in Krylov subspaces (cf. [DeMS15]). For its generality the new method is applicable to any kernels.

Starting from these "fresh" results, the proposed program aims essentially to continue and deepen the following points

(A) study computational improvements on the new fast stable bases studied in [DeMS13, DeMS15]. Moreover it would be interesting to study a new stopping rule for choosing the most significant eigen-couples;

(B) finding approximation of the eigenfunctions in kernel-based spaces. This turns out to be related to the search of "good" points for RBF approximations (cf. [S16, SS16]), in
order to achive a faster decay.

(C) test the reduced basis and "good" points in applications such as in partition of unity methods, in meshless approximation of PDEs and in kernel-based (medical) image reconstruction (cf. [CDeMDeRPS15, DeMISi16, DeMSa16]).
The recent studied "rescaled" RBF interpolant [DeMIdSa16] will be also extensively studied in this framework.

Note: the references are the same as in the program description below

1.6 Settori scientifico-disciplinari interessati dal Programma di Ricerca
Scientific Disciplinary Sectors

MAT/08 MED/36

1.7 Parole chiave
Keywords

1. AREA 01 - Mathematics - Approximations And Expansions - APPROXIMATION BY OPERATORS (IN PARTICULAR, BY INTEGRAL OPERATORS)
2. AREA 01 - Mathematics - Approximations And Expansions - INTERPOLATION
3. AREA 01 - Mathematics - Approximations And Expansions - ABSTRACT APPROXIMATION THEORY (APPROXIMATION IN NORMED LINEAR SPACES AND OTHER ABSTRACT SPACES)
4. Image reconstruction from Radon data, solution of PDEs on unstructured grids

1.8 Curriculum del Responsabile Scientifico del programma di ricerca
Principal Investigator's curriculum

Scholar addresses
1987: degree in Mathematics - University of Padua
1994: Ph.D. in Computational Mathematics and Computer Science, VI-cycle Consortium NE, Padova

Positions helds
* 1995-2005: assistant professor in Numerical Analysis
* 2005-present: associate professor in Numerical Analysis

Conference organization and editorial experience
1. Organizer and member of the scientific committees of 5 conferences on Constructive Approximation
2. Organizer of 7 Research Weeks (workshops) on Constructive Approximation
3. Managing editor of Dolomites Research Notes on Approximation (http://drna.padovauniversitypress.it/)
4. Guest Editor of 6 Special Issues of Conference Proceedings
5. Reviewer for: Siam J. Matrix Analysis and Applications,
Journal of Approximation Theory, J. Comput. Physics, Advances in Computational Mathematics, Numerische Mathematik, Calcolo, Journal of Complexity, Journal of Computational and Applied Mathematics,
Numerical Algorithms, Mediterranean Journal of Mathematics,
Proceedings A Royal Mathematical Society, International Mathematical Journal and Applied Mathematics And - Notes, Computer and Mathematics with Applications, Simulation Modelling Practice and Theory, Adv. Numer. Math., The Scientific World Journal.
6. Reviewer of the AMS Mathematical Review.
7. Reviewer for research projects for: FCT of Portugal, FWO of Holland and SIR of Italy.
8. Member of the Editorial board of: Journal of Pure and Applied Mathematics, Advances and Applications
and The Scientific World Journal (mathematical analysis section)
9. Member of the Editorial board of the book series: MATHEMATICAL AND COMPUTATIONAL BIOLOGY AND NUMERICAL ANALYSIS, Aracne Ed. (Roma).

Scholarships and grants
1. IBM Italy: 1990-1991.
2. CNR (National Research Council): 1994.
3. Post-doc (University of Padova): Feb - Dec 1995.
4. CNR program "Short-term mobility": October 1998 and June 1999.
5. DAAD (Deutscher Akademisher Austauschdienst): July 2001.

Supervisor experience
* 20 theses in Mathematics (6 degree and 14 MSc)
* 1 MSc thesis in Computer Science
* 1 MSc thesis in Applied Mathematics
* 1 Ph.D. thesis

Visiting at Universities: Antwerp, Calgary, Chicago, Dortmund, Giessen, Goettingen, Hamburg, Nashville, Oslo, Valparaiso, Warsaw, Zaragoza.

Exchange Programs
1. CRUI Vigoni Program for 2001/02 with Dortmund and Goettingen.
2. "Bilateral agreement" between the CNR and the DFG: 2006.
3. Erasmus coordinator (presently) with Antwerp, Hamburg, Goettingen, Warsaw.

Research direction and coordination experience
* Founder of the CAA Research Group
* INdAM-GNCS project on "Multivariate approximation by polynomial and radial bases" (2010, funded with 5000 euros).
* Coordinator of ex-60%-DOR of the University of Padova for 2012, 2013, 2014, 2015 and 2016 (funded by 1250 euros in average).
* PI of the "Progetto Ateneo 2012": 29000 euros.

Talks at conferences: 54 (14 as invited or session speaker)
Seminars given in various European, North American and Italian universities. See also http://www.math.unipd.it/~demarchi/Presentations.html for some recent presentation's slides.

Publications
- 62 papers on referred journals
- 14 papers on referred proceedings
- 6 edited proceedings
- 5 submitted papers
- 4 monographs
- Ph.D. and master's theses
- software (see also http://www.math.unipd.it/~demarchi/software.html)
- various research reports and miscellanea mathematical papers

Bibliometrics
- MathSciNet: 57 publications, 227 citations
- Google Schoolar: 896 citations, h-index=16
- Scopus: 49 publications, 347 citations, h-index=11
- ResearchGate: 90 publications, 589 citations, impact points=57.08
- MR Erdos Number=3.

For a complete list of publications, preprints, software and other papers see the web page: www.math.unipd.it/~demarchi/publications.html. For a list a papers related to the present proposal please look at http://www.math.unipd.it/~demarchi/RBF/CAARBF.html

1.9 Pubblicazioni scientifiche più significative del Responsabile Scientifico del Programma di Ricerca

nº	Pubblicazione
1.	De Marchi Stefano (2016). Trivariate polynomial approximation on Lissajous curves. In: Sparse modelling and multi-exponential analysis (Dagstuhl Seminar 15251). vol. 5, p. 68, Dagsthul (Germania), giugno 2015, doi: 10.4230/DagRep.5.6.48
2.	André Pierro de Camargo, Stefano De Marchi (2015). A few remarks on "On certain Vandermonde determinants whose variables separate". DOLOMITES RESEARCH NOTES ON APPROXIMATION, vol. 8, p. 1-11, ISSN: 2035-6803, doi: 10.14658/pupj-drna-2015-1-1
3.	Diego Cecchin, Davide Poggiali, Lucia Riccardi, Paolo Turco, Franco Bui, Stefano De Marchi (2015). Analytical and experimental FWHM of a gamma camera: theoretical and practical issues. PEERJ, vol. 3, ISSN: 2167-8359, doi: 10.7717/peerj.722 -Impact Factor 2.112
4.	S. De Marchi, F. Dell'Accio, M. Mazza (2015). On the constrained mock-Chebyshev least-squares. JOURNAL OF COMPUTATIONAL AND APPLIED MATHEMATICS, vol. 280, p. 94-109, ISSN: 1879-1778, doi: 10.1016/j.cam.2014.11.032
5.	Stefano De Marchi, Gabriele Santin (2015). Fast computation of orthonormal basis for RBF spaces through Krylov space methods. BIT, vol. 55, p. 949-966, ISSN: 0006-3835, doi: 10.1007/s10543-014-0537-6 -Impact Factor .957
6.	Cavoretto R, De Marchi S, De Rossi A, Perracchione E, Santin G (2015). RBF approximation of large datasets by partition of unity and local stabilization. In: (a cura di): J. Vigo-Aguiar, Proceedings of the 15th International Conference on Computational and Mathematical Methods in Science and Engineering. vol. I-II-III-IV, p. 317-326, CMMSE, ISBN: 978-84-617-2230-3
7.	De Marchi Stefano, Piazzon Federico, Sommariva Alvise, Vianello Marco (2015). Polynomial Meshes: Computation and Approximation. In: (a cura di): J. Vigo-Aguiar, CMMSE 2015 : Proceedings of the 15th International Conference on Mathematical Methods in Science and Engineering. vol. I-II-III-IV, p. 414-425, CMMSE, ISBN: 978-84-617-2230-3
8.	S. De Marchi, A. Sommariva, M. Vianello (2014). Multivariate Christoffel functions and hyperinterpolation. DOLOMITES RESEARCH NOTES ON APPROXIMATION, vol. 7, p. 26-33, ISSN: 2035-6803
9.	Stefano De Marchi, Konstantin Usevich (2014). On certain multivariate Vandermonde determinants whose variables separate. LINEAR ALGEBRA AND ITS APPLICATIONS, vol. 449, p. 17-27, ISSN: 0024-3795, doi: 10.1016/j.laa.2014.01.034 -Impact Factor .939
10.	Stefano De Marchi, Marco Vianello (2013). Polynomial approximation on pyramids, cones and solids of rotation. DOLOMITES RESEARCH NOTES ON APPROXIMATION, vol. 6, p. 20-26, ISSN: 2035-6803
11.	Stefano De Marchi, Gabriele Santin (2013). A new stable basis for radial basis function interpolation. JOURNAL OF COMPUTATIONAL AND APPLIED MATHEMATICS, vol. 253, p. 1-13, ISSN: 0377-0427, doi: 10.1016/j.cam.2013.03.048 -Impact Factor 1.077
12.	L. Bos, S. De Marchi, K. Hormann, J. Sidon (2013). Bounding the Lebesgue constant of Berrut's rational interpolant at general nodes. JOURNAL OF APPROXIMATION THEORY, vol. 169, p. 7-22, ISSN: 0021-9045, doi: 10.1016/j.jat.2013.01.004 -Impact Factor .896
13.	Stefano De Marchi, Martina Marchioro, Alvise Sommariva (2012). Polynomial approximation and cubature at approximate Fekete and Leja points of the cylinder. APPLIED MATHEMATICS AND COMPUTATION, vol. 218, p. 10617-10629, ISSN: 0096-3003, doi: 10.1016/j.amc.2012.04.023 -Impact Factor 1.349
14.	K. Hormann, G. Klein, S. De Marchi (2012). Barycentric rational interpolation at quasi-equidistant nodes . DOLOMITES RESEARCH NOTES ON APPROXIMATION, vol. 5, p. 1-6, ISSN: 2035-6803
15.	Bos Len, S. DE MARCHI, Hormann Kai, Klein Georges (2012). On the Lebesgue constant of barycentric rational interpolation at equidistant nodes. NUMERISCHE MATHEMATIK, vol. 121, p. 461-471, ISSN: 0029-599X, doi: 10.1007/s00211-011-0442-8 -Impact Factor 1.329
16.	Stefano De Marchi, Maddalena Mandarà, Anna Viero (2012). Meshfree Approximation for Multi-Asset European and American Option Problems. p. 1-92, Roma:ARACNE editrice S.r.l., ISBN: 9788854851511
17.	L.BOS, S.DE MARCHI, A. SOMMARIVA, M.VIANELLO (2011). Weakly Admissible Meshes and Discrete Extremal Sets. NUMERICAL MATHEMATICS, vol. 4, p. 1-12, ISSN: 1004-8979 -Impact Factor .692
18.	M. CALIARI, S. DE MARCHI, A. SOMMARIVA, M. VIANELLO (2011). Padua2DM: fast interpolation and cubature at the Padua points in Matlab/Octave. NUMERICAL ALGORITHMS, vol. 56, ISSN: 1017-1398, doi: 10.1007/s11075-010-9373-1 -Impact Factor 1.042
19.	L. BOS, S. DE MARCHI, A. SOMMARIVA, M. VIANELLO (2011). On Multivariate Newton Interpolation at Discrete Leja Points. DOLOMITES RESEARCH NOTES ON APPROXIMATION, vol. 4, p. 15-20, ISSN: 2035-6803

20. Bos Len, DE MARCHI Stefano (2011). On optimal points for interpolation by univariate exponent functions . DOLOMITES RESEARCH NOTES ON APPROXIMATION, vol. 4, p. 8-12, ISSN: 2035-6803

21. Len Bos, Stefano DE MARCHI, Kai Hormann (2011). On the Lebesgue constant of Berrut's rational interpolant at equidistant nodes. JOURNAL OF COMPUTATIONAL AND APPLIED MATHEMATICS, vol. 236, p. 504-510, ISSN: 0377-0427, doi: 10.1016/j.cam.2011.04.004 -Impact Factor 1.112

22. Buhmann Martin, S. DE MARCHI, Plonka-Hoch Gerlind (2011). Dolomites Resarch Notes on Approximation (DRNA), Vol. 4, Special Issue for the Proceedings of Robert Schaback's 65th birthday. In: M. D. Buhmann, S. De Marchi, G. Plonka-Hoch. Approximation (DRNA), Vol. 4, Special Issue for the Proceedings of Robert Schaback's 65th birthday. DOLOMITES RESEARCH NOTES ON APPROXIMATION, vol. 4, p. 1-63, VERONA:Università di Verona, ISSN: 2035-6803, Goettingen, 14?15 January 2011

23. Caliari Marco, De Marchi Stefano, Sommariva Alvise, Vianello Marco (2011). Padua2DM: fast interpolation and cubature at the Padua points in Matlab/Octave.

24. DE MARCHI STEFANO, ROBERT SCHABACK (2010). Stability of Kernel-Based Interpolation. ADVANCES IN COMPUTATIONAL MATHEMATICS, vol. 32, p. 155-161, ISSN: 1019-7168, doi: 10.1007/s10444-008-9093-4 -Impact Factor 1.438

25. L. Bos, S. De Marchi, A. Sommariva, M. Vianello (2010). Computing multivariate Fekete and Leja points by numerical linear algebra. SIAM JOURNAL ON NUMERICAL ANALYSIS, vol. 48, p. 1984-1999, ISSN: 0036-1429, doi: 10.1137/090779024 -Impact Factor 1.664

26. Stefano De Marchi, Robert Schaback (2009). Nonstandard Kernels and their Applications. DOLOMITES RESEARCH NOTES ON APPROXIMATION, vol. 2, p. 16-43, ISSN: 2035-6803

27. DE MARCHI S, VIANELLO M., XU Y (2009). New cubature formulae and hyperinterpolation in three variables. BIT, vol. 49, p. 55-73, ISSN: 0006-3835, doi: 10.1007/s10543-009-0210-7 -Impact Factor .648

28. Marco CALIARI, Stefano DE MARCHI, Marco VIANELLO (2008). Algorithm 886: Padua2D-Lagrange Interpolation at Padua Points on Bivariate Domains. ACM TRANSACTIONS ON MATHEMATICAL SOFTWARE, vol. 35, ISSN: 0098-3500, doi: 10.1145/1391989.1391994 -Impact Factor 2.197

29. CALIARI M, DE MARCHI S, VIANELLO M. (2008). Hyperinterpolation in the cube. COMPUTERS & MATHEMATICS WITH APPLICATIONS, vol. 55, p. 2490-2497, ISSN: 0898-1221, doi: 10.1016/j.camwa.2007.10.003 -Impact Factor .997

30. MARCO CALIARI, STEFANO DE MARCHI, MARCO VIANELLO (2008). Bivariate Lagrange interpolation at the Padua points: Computational aspects. JOURNAL OF COMPUTATIONAL AND APPLIED MATHEMATICS, vol. 221, p. 284-292, ISSN: 0377-0427, doi: 10.1016/j.cam.2007.10.027 -Impact Factor 1.048

31. L. BOS, S. DE MARCHI (2008). Univariate Radial Basis Functions with Compact Support Cardinal Functions. EAST JOURNAL ON APPROXIMATIONS, vol. 14, ISSN: 1310-6236

32. Caliari Marco, De Marchi Stefano, Sommariva Alvise, Vianello Marco (2008). Padua2D.

33. Len Bos, Stefano De Marchi, Marco Vianello, Yuan Xu (2007). Bivariate Lagrange interpolation at the Padua points: the ideal theory approach. NUMERISCHE MATHEMATIK, vol. 108, p. 43-57, ISSN: 0029-599X, doi: 10.1007/s00211-007-0112-z -Impact Factor 1.376

34. M. CALIARI, S. DE MARCHI, M. VIANELLO (2007). Hyperinterpolation on the square. JOURNAL OF COMPUTATIONAL AND APPLIED MATHEMATICS, vol. 210, p. 78-83, ISSN: 0377-0427, doi: 10.1016/j.cam.2006.10.058 -Impact Factor .943

35. L. BOS, M. CALIARI, S. DE MARCHI, M. VIANELLO (2006). A numerical study of the Xu polynomial interpolation formula in two variables. COMPUTING, vol. 76, p. 311-324, ISSN: 0010-485X, doi: 10.1007/s00607-005-0137-z -Impact Factor .881

36. CALIARI M, DE MARCHI S, MONTAGNA R, VIANELLO M. (2006). Hyper2d: a numerical code for hyperinterpolation on rectangles. APPLIED MATHEMATICS AND COMPUTATION, vol. 183, ISSN: 0096-3003, doi: 10.1016/j.amc.2006.05.129 -Impact Factor .816

37. BOS L, CALIARI M, DE MARCHI S, VIANELLO M. (2006). Bivariate interpolation at Xu points: results, extensions and applications. ELECTRONIC TRANSACTIONS ON NUMERICAL ANALYSIS, vol. 25, ISSN: 1068-9613 -Impact Factor .738

38. L. Bos, M. Caliari, S. De Marchi, M. Vianello, Y. Xu (2006). Bivariate Lagrange interpolation at the Padua points: the generating curve approach. JOURNAL OF APPROXIMATION THEORY, vol. 143, p. 15-25, ISSN: 0021-9045, doi: 10.1016/j.jat.2006.03.008 -Impact Factor .5

39. L. BOS, S. DE MARCHI, M. VIANELLO (2006). On the Lebesgue constant for the Xu interpolation formula. JOURNAL OF APPROXIMATION THEORY, vol. 141, p. 134-141, ISSN: 0021-9045, doi: 10.1016/j.jat.2006.01.005 -Impact Factor .5

40. S. De Marchi, R. Schaback, H. Wendland (2005). Near-Optimal Data-independent Point Locations for Radial Basis Function Interpolation. ADVANCES IN COMPUTATIONAL MATHEMATICS, vol. 23, ISSN: 1019-7168

41. Marco Caliari, Stefano De Marchi, Marco Vianello (2005). Bivariate polynomial interpolation on the square at new nodal sets. APPLIED MATHEMATICS AND COMPUTATION, vol. 165, p. 261-274, ISSN: 0096-3003, doi: 10.1016/j.amc.2004.07.001

1.10 Componenti il Gruppo di Ricerca
Research-Unit Participants

1.10.0 Professori e ricercatori anche a tempo determinato dell'Università di Padova
University of Padua Researchers

nº	Cognome	Nome	Dipartimento/Istituto	Area scientifica di ateneo	Qualifica	Settore	Mesi/Persona(*) Primo anno	Mesi/Persona(*) Secondo anno	Stato della risposta
1.	CECCHIN	Diego	DIP. MEDICINA	07 - Medicine	Professore Associato (L. 240/10)	MED/36	2	2	
2.	DE MARCHI	Stefano	DIP. MATEMATICA	01 - Mathematics	Professore Associato confermato	MAT/08	8	8	

1.10.1 Professori a contratto di cui all'art. 23 della legge 240/2010, altro Personale dell'Università di Padova anche a tempo determinato (personale tecnico-amministrativo, Dirigenti e CEL)
Other University of Padua Staff

nº	Nome	Dipartimento/Istituto	Qualifica	Mesi/Persona(*) Primo anno	Mesi/Persona(*) Secondo anno

1.10.2 Titolari di assegni di ricerca dell'Università di Padova
University of Padua Research Grants

nº	Cognome	Nome	Dipartimento/Istituto	Area scientifica di ateneo	Mesi/Persona(*) Primo anno	Mesi/Persona(*) Secondo anno

1.10.3 Studenti di Dottorato di Ricerca dell'Università di Padova
University of Padua Students phD Students

nº	Cognome	Nome	Dipartimento/Istituto	Area scientifica di ateneo	Qualifica	Mesi/Persona(*) Primo anno	Mesi/Persona(*) Secondo anno
1.	POGGIALI	Davide	DIP. NEUROSCIENZE SCIENZE NPSRR	07 - Scienze Mediche	Dottorando	2	

1.10.4 Professori, ricercatori anche a tempo determinato di altre Università
Other Universities Researchers

nº	Cognome	Nome	Università	Area scientifica di ateneo	Dipartimento/Istituto	Qualifica	Settore	Mesi/Persona(*) Primo anno	Mesi/Persona(*) Secondo anno
1.	CAVORETTO	Roberto	Università degli Studi di TORINO	01 - Scienze Matematiche	DIP. Matematica Giuseppe Peano	Ricercatore a t.d. - t.pieno (art. 24 c.3-a L. 240/10)	MAT/08	3	3
2.	DE ROSSI	Alessandra	Università degli Studi di TORINO	01 - Scienze Matematiche	DIP. Matematica Giuseppe Peano	Ricercatore	MAT/08	3	3

1.10.5 Dipendenti di altre amministrazioni pubbliche, di enti pubblici o privati, di imprese, di istituzioni straniere, soggetti esterni in possesso di specifiche competenze nel campo della ricerca
Other Personnel

nº	Cognome	Nome	Ente	Qualifica	Mesi/Persona(*) Primo anno	Mesi/Persona(*) Secondo anno
1.	SANTIN	GABRIELE	University of Stuttgart	Post doc	2	2
2.	FASSHAUER	GREGORY	Illinois Instuture of Technology, and from August 1st Colorado School of Mines	Full professor	2	2
3.	ISKE	ARMIN	University of Hamburg	Full professor	2	2
4.	LARSSON	ELISABETH	University of Uppsala	Full professor	2	2

2.1.0 Pubblicazioni scientifiche più significative dei componenti il gruppo di ricerca (docenti dell'ateneo di Padova)
Relevant publications of the Research Group (Universtity of Padua Researchers)

nº	Pubblicazioni
1.	Cecchin D, Schiorlin I, Della Puppa A, Lombardi G, Zucchetta P, Bodanza V, Gardiman MP, Rolma G, Frigo AC, Bui F (2014). Assessing Response Using (99m) Tc-MIBI Early after Interstitial Chemotherapy with Carmustine-Loaded Polymers in Glioblastoma Multiforme: Preliminary Results.. BIOMED RESEARCH INTERNATIONAL, vol. 2014, ISSN: 2314-6133, doi: 10.1155/2014/684383
2.	Diego Cecchin, Davide Poggiali, Lucia Riccardi, Paolo Turco, Franco Bui, Stefano De Marchi (2015). Analytical and experimental FWHM of a gamma camera: theoretical and practical issues. PEERJ, vol. 3, ISSN: 2167-8359, doi: 10.7717/peerj.722
3.	Rossato Marco, Cecchin Diego, Vettor Roberto (2016). Brown adipose tissue localization using (18)F-FDG PET/MRI in adult. ENDOCRINE, p. ..., ISSN: 1355-008X, doi: 10.1007/s12020-015-0847-8

2.1.1 Pubblicazioni scientifiche più significative dei componenti il gruppo di ricerca (altri partecipanti al progetto)
Relevant publications of the Research Group (Other participants)

[S16] Santin G.: Approximation in kernel-based spaces, optimal subspaces and approximation of eigenfunctions, Ph.D. thesis, University of Padova, XXVIII ciclo (2016).

[SS15] Santin G. and Schaback R.: Approximation of eigenfunctions in kernel-based spaces, Adv. Comput. Math. (2016), online.

[PIT13] Plonka, Gerlind; Iske, Armin; Tenorth, Stefanie: Optimal representation of piecewise Hölder smooth bivariate functions by the easy path wavelet transform. J. Approx. Theory 176 (2013), 42-67.

[DI15] Demaret, Laurent; Iske, Armin: Optimal N-term approximation by linear splines over anisotropic Delaunay triangulations. Math. Comp. 84 (2015), no. 293, 1241-1264.

[CFMcC15] Cavoretto, Roberto; Fasshauer, Gregory E.; McCourt, Michael: An introduction to the Hilbert-Schmidt SVD using iterated Brownian bridge kernels. Numer. Algorithms 68 (2015), no. 2, 393-422.

[FMcC12] Fasshauer, Gregory E.; McCourt, Michael J.: Stable evaluation of Gaussian radial basis function interpolants. SIAM J. Sci. Comput. 34 (2012), no. 2, A737-A762.

[SRFH12] Song, Guohui; Riddle, John; Fasshauer, Gregory E.; Hickernell, Fred J.: Multivariate interpolation with increasingly flat radial basis functions of finite smoothness. Adv. Comput. Math. 36 (2012), no. 3, 485-501.

[C15] Roberto Cavoretto: Two and three dimensional partition of unity interpolation by product-type functions, Applied Mathematics & Information Sciences 9(2015), 1-8.

[ABCDeR10_1] Giampietro Allasia, Renata Besenghi, Roberto Cavoretto, Alessandra De Rossi: Efficient approximation algorithms. Part I: approximation of unknown fault lines from scattered data, Dolomites Res. Notes Approx. 3 (2010), 7-38

[ABCDeR10_2] Giampietro Allasia, Renata Besenghi, Roberto Cavoretto, Alessandra De Rossi: Efficient approximation algorithms. Part II: scattered data interpolation based on strip searching procedures, Dolomites Res. Notes Approx. 3 (2010), 39-78

2.2 Descrizione del Programma di Ricerca
Description of the research program

In the multivariate polynomial setting many efforts has been done in the direction of looking for nearly optimal interpolation points on general domains (see e.g. the work done by CAA research group in http://www.math.unipd.it/~marcov/CAA.html on Padua points and discrete extremal sets extracted from (weakly) admissible meshes) and finding more stable polynomial
bases (mainly orthonormal) for the corresponding compact.
In the framework of Radial Basis Functions (RBF) approximation, since 2005 the proponent has worked for finding good points for data-independent interpolation problems
opening then new directions of study for stability issues (stable bases and convergence rates) in function spaces for RBF interpolation problems [DeMSW05, DeMSc10] (for the research activity of the CAA research group on the topic, please look at
http://www.math.unipd.it/~demarchi/RBF/CAARBF.html).

The research program can be organized in three main parts.

(A) Possible computational improvements of the new fast stable basis studied in [DeMS13, DeMS14].

(B) Approximation of eigenfunctions in kernel-based spaces (cf. [S16, SS15]), which turns out to be related to the search of "good" points for RBF approximations.

(C) Applications of the reduced-stable bases and "good" points in partition of unity methods, in meshless approximation of PDEs and in kernel-based image reconstruction [CDeMDeRPS15, DeMISi16, DeMISa16].

Here we provide a more extensive description of each parts.

(A) In the setting of Radial Basis Function (RBF) approximation, some efforts has been made to construct basis which allows
to better compute the approximant, both from the point of view of convergence and of stability. Recently we have proposed the so-called weighted SVD basis [DeMS13] and a faster technique to compute this basis using methods based on Krylov subspaces [DeMS14]. The new fast method to compute the WSVD basis has shown
to be very effective both from the point of view of the computational time and the approximation feautures. The reasons for the study of this new fast method was the slowness of the computation of the WSVD basis, as improved then in [DeMS15]. On the other hand, thanks to the fact that the new basis is built using also information coming from the sampling of the
unknown function, we are now able to obtain a better approximation. The approximant is very general, independent of the special kernel used. Some features of the "reduced basis method" (as known in engineering applications) need further investigations (stopping rule, convergence analysis), including the applications to generalized interpolation problems and solution of PDEs.

(B) Kernel-based methods have the advantage to be an optimal recovery processes in the ”native” reproducing Hilbert space H in which they are reproducing. Continuous kernels on compact domains have an expansion into eigenfunctions that are both L2-orthonormal and orthogonal in H (known as Mercer expansion). In the paper

[SS16] the authors, extending results in [S16], study the corresponding eigenspaces and prove that they have optimality properties among all other subspaces of H. These results have strong
connections to n-widths, and they establish that errors of optimal approximations are closely related to the decay of the eigenvalues. We want to investigate more deeply on error bounds for the numerical approximation of the eigensystem via such subspaces (as already done in [SS15]). This problem allows a greedy point selection and so it is intimely related to the problem of finding "good" points for RBF approximations (cf. also [S14, DeMSW05]).

(C) In the recent paper [C15] the authors propose a new method for multivariate approximation (with examples in 2 and 3 dimensions) which allows to interpolate large scattered data sets stably, accurately and with a relatively low computational cost.
Focusing on RBF interpolants, the partition of unity approach is performed by blending RBFs as local approximants and using
locally supported weight functions. With this approach a large problem can be decomposed into smaller ones, allowing to work with large number of nodes. However, in some cases local approximants and consequently also the global one, may suffer from instability due to the typical ill-conditioning of the interpolation matrices. This
is directly connected to the order of smoothness of the basis function and to the node distribution. It is well-known that the stability depends on the flatness of the RBF. Specifically, for a flat basis function the condition number of the interpolation (or kernel) matrix might be quite severe, while a peaked one can be used to improve the conditioning but the accuracy of the fit gets worse ("trade-off" principle).
For gaussians, techniques allowing to stably and accurately compute the interpolant have been studied in the seminal papers [FLF11, FMcC12], by producing two well-established numerical methods: the RBF-QR and the RBF-Direct.
For this reason, the recent research has moved to the study of more stable bases non only for the gaussian case. The more general approach, via a truncated Singular Value Decomposition (SVD) has been presented and studied in [DeMS13, DeMS15]. Why this idea can be useful for Partition of Unity (PoU) method?
Basically, the PoU method is obtained by blending local RBF interpolants and using compactly supported weight functions. Our idea instead consists, for each PoU subdomain, compute/praduce a stable RBF basis in order to solve the local interpolation problem. Consequently, since the local approximation order is preserved for the global fit, the interpolant will result more stable and accurate. Moreover, in terms of accuracy, the benefits coming from the use of such stable bases are more significant in a local approach than in a global one. In fact, generally, while in the global case a large number of truncated terms of the SVD must be dropped to preserve stability, a local partition of unity technique requires only few terms are eliminated, thus enabling the method to be much more accurate.
Concerning the computational complexity of the algorithm, the use of the so-called kd-tree space partitioning data structure, which successfully works in any space dimension, enables us to efficiently organize points among the different subdomains. Then, for each subdomain a local RBF problem is solved with the use of a stable basis. The main and truly high cost, involved in this step, is the computation of the SVD. To avoid this drawback, we can resort to techniques based on Krylov space methods, since they turn out to be really effective (cf. [DeMS15]). We then need to study the complexity of our method on kernels with different orders of smoothness,
both globally and compactly supported and on various data sets. A first attempt to solve this problem has recently done in [CDeMDeRPS16].
Inspired by the work [DFQ14] for large-scale scattered problem, we can work in another direction by using the so-called "rescaled" RBF interpolation by compactly supported basis functions
(which turns out to be a Shepard approximation), which has found interest in the solutions of PDEs on unstructured grids (cf. [DFQ14, DeMIdSa16]]).

The application of kernel-based medical image reconstruction from scattered Radon data (CT application), is a novel research that we want to continue to investigate, supported by the promising results recently obtained [DeMISi16],
showing the good performance of the regularized kernel-based image reconstruction method (which is a generalized Hermite-Birkhoff interpolation problem) in comparison with classical Fourier based methods.
We are quite confident that the application of the Newton basis [MS09] for the selection of the most "suitable" Radon lines (in the case of random lines geometry) can be helpful to reduce the complexity, the stability and the computational cost of the reconstruction process [DeMISa16].
Finally, there is a another research direction that has room for an RBF approximation, that is medical image registration for motion detection and correction. A recent MSc thesis has already investigated
this problem with interesting results (cf. Ada Passerini: "Medical Image Registration for Motion Detection and Correction", MSc thesis, Department of Mathematics, Dec. 2015. Supervisors: De Marchi Stefano and Davide Poggiali)

The last application will be done also in collaboration with the Medical School of the University of Padova which will provide real data on which test the technique.

As a note, the collaboration with the Medical School, Section of Nuclear Medicine, in particular with Prof. D. Cecchin, is an ongoing collaboration that needs more support: the present proposal is aimed to provide more hints and possibilities.

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2.3 Obiettivo del Programma di Ricerca e, nel caso di assegni di ricerca, indicazione dei risultati attesi dall'attività dell'assegnista/assegnisti previsti alla fine del prio anno e a conclusione della ricerca
Short-term and long-term goals and expected results

The program consists essentially of two theoretical parts, in which the candidate should enhance the results concerning the new reduced-stable basis of native spaces of kernel-based approximation, and one devoted to applications of the new reduced-stable basis to PoU methods, solution of generalized Hermite-Birkhoff interpolation problems in CT image reconstruction and registration, in collaboration with the medical school of Padova.
and moreover the solution of PDEs on unstructured grid with the "rescaled" RBF interpolant.

Concerning the theoretical parts, the candidate should have a strong background in kernel-based approximation (radial basis functions approximation), operator theory (mainly with positive definite kernels) and functional analysis.
It is also required a strong preparation in numerical analysis and numerical algorithms. A very good knowledge of programming languages, like C (or C++) and Matlab-like, is also required. In fact, as detailed in the project program, we would like to test in practical applications the performance of the reduced-stable basis, in generalized interpolation problems, in (medical) image reconstruction or image registration and solution of PDEs on unstructured grids by the rescaled RBF interpolant.

Furthermore, the proposed project will be developed in collaboration with international and local collaborators, with whom the proponent has already established active research contacts, wrote papers and other scientific collaborations (Erasmus+, MSc and Ph.D. theses).
For parts (A) and (B) with the collaboration of Prof. Gregory Fasshauer (Illinois Institute of Technology - Chicago) and Elisabeth Larsson (University of Uppsala - Sweden).
For the applications described in the parts (A) and (C), with two colleagues from the Medical School of the University of Padova (dr. Diego Cecchin, Department of Medicine and Mr. Davide Poggiali, Ph.D. student at the Department of Neuroscience), two collegues of the University of Torino (dr. Alessandra De Rossi and dr. Roberto Cavoretto) and Prof. Armin Iske (University of Hamburg - Germany).

It is indeed evident from the bibliography listed in various sections of this proposal, the active and necessary interactions with these people.

The scheduling for the proposed research can be summarized as follows.

1. The candidate, after a comprehension of the problem and the state of art of stability problems in kernel-based approximation (with special attention to the construction of stable bases), he/she has to investigate and analyze new ideas in computing and solving the reduced-basis problem and some of its applications, as outlined at the points (A),(B) and (C) of the research program.
For the proposed research the candidate should also contribute to the DOR research program 2016 "Approximation by radial basis functions and polynomials: applications to MRI and MPI", supported by the University of Padova, of which the coordinator is the principal investigator.

2. The collaboration with the people indicated in the proposal is a key issue. They are the major experts in many aspects of the proposal and can help and lead the candidate in finding new ideas and solutions. In particular, concering the application to medical image reconstruction and registration, a continuous collaboration with the Department of Medicine, section of Nuclear Medicine, is very important for part (C) of the program.

3. Another aspect is the production of a comprehensive Matlab (but not necessarily) package for
(i) constructing and analyzing the new reduced basis;
(ii) optimal points location analysis;
(iii) applications, such as partition of unity, meshless approximation of PDEs on unstructured grids and image reconstruction registration by radial basis functions.

We assume that the candidate should dedicate half of the first year to the point 1., while to the points 2. and 3., the remaining one and half year. The hope is a suitable productions of some scientific papers to be submitted to international journals, conference proceedings of applied or numerical mathematics.

2.4 Informazioni aggiuntive
More informations

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3.0 Costo del Programma
Program Cost
3.1 Assegni di ricerca da attivare in questo Programma di Ricerca
Research Grants

nº	Attività specifica nel progetto e competenze	Durata complessiva (mesi)	Costo complessivo assegno [1] (euro)	Quota cofin disponibile [2] (max 50%)	Tipologia dei fondi utilizzati a cofin [3]	Quota cofin chiesta al dipartimento
1.	Suporting the researcher for two years for: (i) analysis of the problem (ii) implementation and numerical tests (iii) applications (Partition of Unity, Meshless approximation, image reconstruction).	24	46.926			46.926
	TOTALE		**46.926**	**0**		**46.926**

Dichiarazione / Declaration

Il presente progetto NON prevede sperimentazione animale

Il Responsabile della Ricerca: .....

Padova lì, 14/06/2016 15:44