nDS'15

Program and Abstracts of the

2015 IEEE 9th International Workshop on MultiDimensional Systems (nDS)

Vila Real, Portugal
Sep. 7 – 9, 2015

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E. J. Solteiro Pires and T-P Azevedo Perdicoúlis

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Welcome Message

The 9th edition of the biannual International Workshop in Multidimensional Systems, IEEE nDS2015, takes place at the University of Trás-os-Montes e Alto Douro (UTAD), Vila Real, Portugal, between the 7th and the 9th of September 2015. This University is located in the UNESCO World Heritage Site of Douro Valley as well as in the Magnificent World of Miguel Torga, a very famous portuguese writer of this region. The region is famous by its fantastic wines as well as its awesome landscapes and people's hospitality.

The workshop presents the state of the art and most recent advances in the theory and applications of multidimensional systems. Moreover, it provides a forum for bringing together researchers from a variety of different scientific areas and application fields. This year workshop follows the tradition of its eight previous editions in Lagów 1998, Czocha 2000, Notre Dame 2002, Wuppertal 2005, Aveiro 2007, Thessaloniki 2009, Poitiers 2011 and Erlangen.

In this year's Workshop on Multidimensional Systems (IEEE nDS13), we are privileged to announce its three distinguishing invited speakers:

Professor Ettore Fornasini from the Università di Padova, Italy, to speak about *2D Boolean Control Networks*.

Professor Rudolf Rabenstein from the Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany, to talk about *Modelling and Simulation of Physical Systems with Multidimensional Transfer Functions*.

Professor José A. Ramos from the Nova Southeastern University, (FL) USA, USA, to present *An Overview of 2-D State Space System Identification Theory*.

Furthermore, a special session is organised by Raquel Pinto, Paula Rocha and Maria Elena Valcher in honour of Professor Fornasini, on the occasion of his 70th birthday, and his many and decisive contributions to the field of Multidimensional Systems. In addition, another session is organised by Nima Yeganefar and the french community on stability and stabilization in multidimensional systems.

The individual contributions by the workshop participants present research on *Theory and Applications of nD Systems*, *Stability*, *Stabilization*, *Circuits*, *Physical Systems*, *Video Scene Analysis Image Processing* and *Repetitive Processes*.

The workshop has received organizational support by IEEE Portugal Section, IEEE Circuits and Systems Society, Portugal Section BT/CAS/CE Joint Chapter and the University of Trás-os-Montes e Alto Douro.

The CAS Society provides technical co-sponsorship and conveys online publication of the proceedings via IEEE Xplore. The local support is provided by the Universidade de Trás-os-Montes e Alto Douro.

Sincere thanks go to the members of the local organizing committee for their diligent work in preparing and conducting this workshop. The various tasks have been shared by Eduardo Solteiro Pires, Paulo Moura Oliveira, José Boaventura and Paulo Lopes dos Santos.

Be very welcome at UTAD!

Teresa A. Perdicoúlis, Krzysztof Galkowski, and Eric Rogers

Vila Real, September 2015.

Program at a Glance, IEEE nDs 2015

Monday	Tuesday	Wednesday
	8:45–9:45 **Keynote** Ettore Fornasini	8:45–9:45 **Keynote** Rudolf Rabenstein
9:00–9:30 **Registration**		
9:30–10:00 **Openning**		
10:00–11:00 **Keynote** José A. Ramos	9:50–11:10 **Special Session 2** **Part I** R Pinto, P. Rocha, M. E. Valcher	9:50–11:10 **Special Session 2** **Part II** R Pinto, P. Rocha, M. E. Valcher
11:00–11:40 **Cofee Break**	11:10–11:40 **Cofee Break**	11:10–11:40 **Cofee Break**
11:40–13:00 **Special Session 1** **Part I** Nima Yeganefar	11:40–13:00 **Special Session 1** **Part II** Nima Yeganefar	11:40–13:00 **Regular Session** Stability and Stabilization
13:00–14:20 **Lunch**	13:00–14:20 **Lunch**	13:00–14:20 **Lunch**
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15:50–16:20 **Cofee Break**	15:30–23:00 **Social Program** **and** **Conference Dinner**	15:50–16:20 **Cofee Break**
16:20–17:50 **Regular Session** Wave nD Systems		16:20–17:20 **Regular Session** Theoretical Adv. in $2D$ Syst.
		17:30–18:30 **Closing**
19:00–21:00 **Welcome Drink**		

An Overview of 2-D State Space System Identification Theory

José A. Ramos
College of Engineering and Computing
Nova Southeastern University, (FL) USA

Abstract

In this plenary talk a brief overview of 2-D state space system identification theory and its applications will be presented. There is a large body of literature on 2-D systems, ranging from the traditional difference equation type autoregressive moving average (ARMA) models, to nearest neighbour models used in image processing, and then there are the state-space models which include among others, those independently introduced by Roesser-Givone, Fornasini-Marchesini, Attasi, and Kurek. The Roesser model class has also found wide spread applications in iterative learning control and currently represents an active area of research. Since most of the other 2-D state-space models can be transformed into a Roesser model, attention will be given to the Roesser model. There are essentially three types of problems to be addressed here:

1. The purely stochastic case, where only the output is known and the input is assumed to be an unknown 2-D white noise process. This could lead to time/time, space/time, time/space, and space/space models. This model is used in image modeling and texture generation.

2. The purely deterministic case, where both the input and output are assumed to be deterministic and the system is noise-free. Partial differential equations (i.e., a heat exchanger model) fall into this category.

3. The combined deterministic-stochastic case, where the system contains process and measurement noise. This is the most general case within the linear class of 2-D state space models.

Recent research in 2-D system identification theory has led to the use of subspace-based algorithms. These algorithms have been known to be robust to

noise in the data, they require a minimum intervention from the user, and are not iterative. However, for the above three Roesser models, there are no known subspace-based algorithms that can identify the general case of a non-separable transfer function. There are still some unanswered questions. An explanation will be given as to why this is a challenging problem, what are the main challenges, and then present a solution that exploits the problem structure. In essence the non-separable problem becomes a structured system identification problem. Examples of the proposed algorithms will be presented.

About the Speaker:

Dr. José A. Ramos is currently the Chair of Computer Engineering at Nova Southeastern University in Florida, where he teaches circuits, computer programming, discrete mathematics, numerical analysis, design and analysis of algorithms, and digital design. His research interests are in the areas of subspace system identification theory and algorithms, applied optimization, multivariate data analysis, image processing, and numerical linear algebra. He has been a visiting researcher at the Katholieke Universiteit Leuven in Belgium, the University of Montpellier II in France, The University of Porto in Portugal, and the University of Padova in Italy.

2D Boolean Control Networks: A Progress Report

Ettore Fornasini
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Abstract

1D Boolean Control Networks (BCN's), and in particular 1D Boolean Networks (BN's), have recently witnessed a large interest as effective tools for investigating a number of biological phaenomena and technological models, whose variables display a finite number of operation levels.

The purpose of this paper is to discuss some problems that arise when an extension of 1D BCN theory to a 2D environment is endeavored. 2D BCN's are 2D systems whose (local) states $x(i,j)$, inputs $u(i,j)$ and outputs $y(i,j), i,j \in \mathbb{Z}$ take values in three finite alphabets X, U and Y, and update according to the following equations

$$x(i+1,j+1) = f(x(i,j+1), x(i+1,j), u(i,j+1), u(i+1,j)) \quad (1)$$
$$y(i,j) = h(x(i,j)) \quad (2)$$

Here $f : X \times X \times U \times U \to X$ and $h : X \to Y$ are arbitrary maps.

In particular, when the state dynamics (1) is autonomous, we are faced with a 2D BN. The global states $\chi_\nu = \{x(i, i+\nu), i \in \mathbb{Z}\}$ can be viewed as shift spaces over the local state alphabet X and the evolution map

$$\phi : \chi_\nu \to \chi_{\nu+1} \quad (3)$$

is the sliding block code induced by the 2-block map $x(i+1,j+1) = f(x(i,j+1), x(i+1,j))$. Asymptotic stability, i.e. the convergence of (3) to a unique constant sequence of local states, say $\bar{\chi} = (...0,0,0,...)$, in a finite number of steps and independently of the initial global state χ_0, is discussed and related to the behavior of a series of infinitely many identical 1D BCN's.

About the Speaker:

Ettore Fornasini received the "Laurea" degree in Electronic Engineering and in Mathematics from the University of Padova, Italy, in 1969 and in 1973, respectively. In 1972 he joined the Department of Information Engineering (formerly Istituto di Elettronica e di Elettrotecnica) of the University of Padova, where he taught Electrical Network Theory, Automatic Control, System Theory, Multivariable Systems (polynomial methods) and Positive Systems Theory. He has also been responsible for lectures and courses of doctoral schools in Italy, Portugal and Austria. In 1980 E.Fornasini was appointed full professor of Mathematical Systems Theory. From 1993 to 2001, he chaired the Board of the Degree in Computer Engineering and in Electronic Engineering, and coordinated the committee for the reform of studies in the courses of Information Engineering. In 2002-05 and 2005-08 he has been elected dean of the Faculty of Engineering and in 2009-12 member of the Administration Board of the University of Padova.

He spent research periods at the Center for Mathematical System Theory, Gainesville (Florida), at the MIT Laboratory for Information and Decision Systems, Cambridge (Massachusetts), at the Technical University of Delft (The Netherlands), at the University of Innsbruck (Austria), at the University of Aveiro (in 2010, 13, 14) and has been invited to give lectures at various foreign universities: Wurzburg, Prague, Aveiro, Delft, Innsbruck, Pennsylvania State University, etc. He has been associate editor of *Circuit Systems and Signal Processing* and editor of *Multidimensional Systems and Signal Processing*. He also exercised functions as a referee of research projects of the NSF and the research projects funded by MURST.

E.Fornasini is the author of over one hundred and sixty scientific papers in the field of Dynamical Systems Theory and Control, which were published in international journals or presented, often by invitation, at international conferences. His first research interests included the realization problem of bilinear systems, the structure of dissipative dynamical systems, and the connectivity properties of linear systems. In 1973 he began to collaborate with G.Marchesini on the theory of multidimensional systems: his joint work with G. Marchesini

and, subsequently, with M. Bisiacco, M. Sebek, S. Zampieri, P. Rocha, M. E. Valcher, R. Pinto, and T. Pinho allowed to obtain several results concerning realization, stability, feedback stabilizability, failure detection, noninteracting and optimal control of 2D systems, 1D and nD coding theory, 2D Markov chains and their asymptotic behavior, 2D positive systems, with particular reference to the algebraic aspects of the pairs of non-negative matrices, nD behaviour theory, and some applications of 2D systems to river pollution and traffic modelling. In the last few years, E.Fornasini collaborated with M. E. Valcher to the investigation of positive switched dynamical systems and boolean control networks.

Modelling and Simulation of Physical Systems with Multidimensional Transfer Functions

Rudolf Rabenstein
Friedrich-Alexander-Universität Erlangen-Nürnberg
Germany

Abstract

The transfer function approach to modelling and simulation of physical systems can be summarized by a few steps: The most common mathematical description of multidimensional physical systems are partial differential equations. The spectral decomposition of their differential operators leads to an alternate system representation in the form of multidimensional transfer functions. For computer implementation a discrete-variable representation is required which can be obtained by suitable continuous-to discrete transformations. Finally signal processing algorithms lead to efficient realizations including real-time implementations.

This talk describes these steps in more detail, reviews some recent applications in audio and acoustics and gives an outlook to new problems.

About the Speaker:

Rudolf Rabenstein studied Electrical Engineering at the University of Erlangen-Nuremberg, Germany, and at the University of Colorado at Boulder, USA. He received the degrees "Diplom-Ingenieur" and "Doktor-Ingenieur" in electrical engineering and the degree "Habilitation" in signal processing, all from the University of Erlangen-Nuremberg, Germany in 1981, 1991, and 1996, respectively. He worked with the Physics Department of the University of Siegen, Germany, and now as a Professor with the Telecommunications Laboratory at the University of Erlangen-Nuremberg. His research interests are in the fields

of multidimensional systems theory and multimedia signal processing. Previous service includes a membership of the Technical Committee for Signal Processing Education of the IEEE Signal Processing society and several editorial tasks for IEEE publications. Currently he is an associate editor of the Springer journal Multidimensional Systems and Signal Processing.

Special Session 1: Recent Advancements in the French Community on Stability and Stabilization

Organizer: Nima Yeganefar.

Session outline: In 2014, several members of the French community working on nD systems got a national grant funded by the Agence National de la Recherche (grant ANR-13-BS03-0005). The questions are around the problem of stability and stabilisation of multidimensional systems. this invited session proposes to show the advancements recently obtained in this area and the wide range of methods used to tackle the problems. A few papers also focus on some old questions specific to the nD community; for instance the equivalence of the famous Roesser/Fornasini-Marchesini models or the existence of the solutions of the nonlinear Roesser model.

List of papers:

- *State Feedback Structural Stabilization of 2D Discrete Roesser Models*; Olivier Bachelier, Nima Yeganefar, Driss Mehdi and Wojciech Paszke.

- *Existence and Uniqueness of the Solutions of Continuous Nonlinear 2D Roesser Models: The Locally Lipshitz Case*; Ronan David, Francisco J. Silva, Nima Yeganefar and Olivier Bachelier.

- *Computer Algebra Techniques for Testing Efficiently the Structural Stability of Multi-dimensional Systems*; Yacine Bouzidi, Alban Quadrat and Fabrice Rouillier.

- *A Constructive Algebraic Analysis Approach to the Equivalence of Multidimensional Linear Systems*; Thomas Cluzeau.

- *Euler Bernoulli Beam Flatness based Control with Constraints*; Maria Bekcheva, Luca Greco, Hugues Mounier and Alban Quadrat.

Special Session 2: New Trends in Multidimensional System Theory. Celebrating Ettore Fornasini's 70th Birthday

Organizers: Maria Elena Valcher, Paula Rocha, Raquel Pinto

Session outline: In this session we intend to celebrate the 70th birthday of Ettore Fornasini and his many and crucial contributions to the Theory of Multidimensional Systems. Ettore's research started in the early seventies with some fundamental contributions that laid the foundations of the so-called Fornasini Marchesini 2D state-space model. Subsequently, his research activity focused on the study of abstract properties of 2D and nD behaviors and on their application to more application oriented topics like 2D convolutional codes and river pollution modeling. He also introduced 2D positive state-space models to describe ecological systems or to cope with traffic problems. The session consists of the following seven communications by some of the many authors that have been inspired by his work.

List of papers:

- *The Fornasini-Marchesini Model — Its Role in the Analysis and Control of Physical Systems*; Eric Rogers.
- *State Representations of Finitely Generated 2D Behaviors over Rings*; Eva Zerz.
- *Self-boundedness and Self-hiddenness for Implicit Two-dimensional Systems*; Lorenzo Ntogramatzidis.
- *Characterization of nD Systems with Symmetries*; Paolo Vettori.
- *On the Control and Dead-beat Control of 2D Time-relevant Behaviors*; Mauro Bisiacco and Maria Elena Valcher.
- *State Representations of Autonomous 2D Kernel Behaviors using the Fornasini- Marchesini Model*; Isabel Brás and Paula Rocha.
- *Analysis of Composition Codes*; Telma Pinho, Raquel Pinto and Paula Rocha.

Regular Session: Applications of nD Systems

- Slawomir Mandra, Krzysztof Gałkowski, Harald Aschemann and Andreas Rauh. *Guaranteed Cost Iterative Learning Control – An Application to Control of Permanent Magnet Synchronous Motors.*
- Pedro Miguel Rodrigues, Diamantino Freitas and João Paulo Teixeira. *Alzheimer's Electroencephalogram Event Scalp Localization.*
- Vishwa Seneviratne, Arjuna Madanayake and Nilan Udayanga. *Wide-band 32-element 200-MHz 2-D IIR Beam Filters using ROACH-2 Virtex-6 sx475t FPGA.*
- Anna Heinemann, Jörg Velten and Anton Kummert. *Map Building using Occupancy Grids with Differentiated Occupancy States.*

Regular Session: Wave nD systems

- Bartłomiej Sulikowski, Krzysztof Gałkowski and Anton Kummert. *Stability and Stabilisation of Active Ladder Circuits Modeled in the Form of Two-Dimensional (2D) Systems.*
- Petr Augusta, Blazej Cichy, Krzysztof Gałkowski and Eric Rogers. *An Unconditionally Stable Finite Difference Scheme Systems Described by Second Order Partial Differential Equations.*
- Tim Schwerdtfeger and Anton Kummert. *Newton's Method for Modularity-preserving Multidimensional Wave Digital Filters.*
- Suranga Handagala, Arjuna Madanayake and Nilan Udayanga. *Design of a Millimeter-Wave Dish-Antenna based 3-D IIR Radar Digital Velocity Filter.*

Regular Session: Stability and Stabilisation

- Pavel Pakshin, Julia Emelianova, Krzysztof Gałkowski and Eric Rogers. *Stabilization of Nonlinear 2D Fornasini - Marchesini Systems.*

- Jörg Velten, Anton Kummert and Krzysztof Gałkowski. *Application Specific Stability of 3-D Roesser-like Model Realizations.*

- Eduardo Solteiro Pires, Paulo Moura Oliveira and José Tenreiro Machado. *Meta-heuristics in Multidimensional Systems Stability Study.*

- Pavel Pakshin, Julia Emelianova, Mikhail Emelianov, Krzysztof Gałkowski and Eric Rogers. *Stabilization of Stochastic 2D Fornasini–Marchesini Systems.*

Regular Session: Vision

- Carsten Stahlschmidt, Alexandros Gavriilidis and Anton Kummert. *Classification of Ascending Steps and Stairs using Time-of-Flight Sensor Data.*

- Alexandros Gavriilidis, Carsten Stahlschmidt, Jörg Velten and Anton Kummert. *Evaluation of Pedestrian Detection Fusion and Localization based on the Idea of Car-To-X Communication.*

- Kathrin Kalischewski, Daniel Wagner, Jörg Velten and Anton Kummert. *Orientation and Positioning with Inertial Sensors for Walking Frame Guidance.*

- Daniel Wagner, Kathrin Kalischewski, Jörg Velten and Anton Kummert. *Detection of Ascending and Descending Stairways by Surface Normal Vectors.*

- Thomas Sablik, Jörg Velten and Anton Kummert. *Censorship of Video Images with Adaptive Reconstruction Based on Spectral Domain Watermarking.*

Regular Session: Theoretical Advances in 2D Systems

- Marek Majewski and Andrzej Skowron. *On some 2D Integro-differential Control Problem.*
- Joan-Josep Climent, Diego Napp, Raquel Pinto and Rita Simões. *Series Concatenation of 2D Convolutional Codes.*
- Konrad Markowski. *Determination Minimal Positive Realisation of One-Dimensional Continuous-Time Fractional Linear System.*
- Teresa Paula Azevedo Perdicoulis, Gerhard Jank and Paulo Lopes Dos Santos. *Nash Equilibrium with Wave Dynamics and Boundary Control.*

Special Session 1 – Part I: Recent Advancements in the French Community on Stability and Stabilization

Session chair: Nima Yeganefar

Monday 11:40 – 13:00

State Feedback Structural Stabilization of 2D Discrete Roesser Models

Olivier Bachelier, Nima Yeganefar, Driss Mehdi and Wojciech Paszke

Abstract

In the previous edition of nDS, a Linear Matrix Inequality (LMI)-based necessary and sufficient condition to test the structural stability of 2D discrete linear Roesser models was proposed. This note hinges on this condition and proposes the first numerically tractable necessary and sufficient condition for state feedback structural stabilization of such models.

Existence and Uniqueness of the Solutions of Continuous Nonlinear 2D Roesser Models: The Locally Lipschitz Case

Ronan David, Francisco J. Silva, Nima Yeganefar and Olivier Bachelier

Abstract

This paper investigates the existence and uniqueness of the solution of the nonlinear continuous 2D Roesser model. We first remind the reader of the results obtained in the globally Lipschitz case where a global solution is always to be found. Then we investigate the more general case which could be applied in more situations: when the function describing the system is only supposed locally Lipschitz. Since in this case the solution will be defined only locally, the question of whether we can extend the solutions or not is answered.

Regular Session: Applications of nD Systems

Session chair: Krzysztof Galkowski

Monday 14:30 – 15:50

Guaranteed Cost Iterative Learning Control - An Application to Control of Permanent Magnet Synchronous Motors

Slawomir Mandra, Krzysztof Gałkowski, Harald Aschemann and Andreas Rauh

Abstract

This paper addresses the design of iterative learning control laws (ILC) for both trial-to-trial error convergence and along-the-trial performance. It is shown how these control laws can be designed using the theory of discrete linear repetitive processes in combination with a guaranteed cost control approach. The parameterization of the controllers is performed by the solution of linear matrix inequalities (LMIs). The paper is concluded with experimental results for the position control of a Permanent Magnet Synchronous Motor (PMSM).

Alzheimer's Electroencephalogram Event Scalp Localization

Pedro Miguel Rodrigues, Diamantino Freitas and João Paulo Teixeira

Abstract

Alzheimer's disease (AD) is a neurodegenerative and incurable illness that causes intellectual functions decrease. This study is a new approach to improve the scalp brain anomalies localization associated with Electroencephalogram (EEG) energy variations of EEG threads (subsegments) sequencies sets found in AD patients by unsupervised learning techniques, called AD EEG temporal events. This study showed that AD patients have less brain dynamics than controls, because the AD EEG events propagation time over the scalp is higher and statistically different from control subjects ($p < 0.0022$)

Wideband 32-element 200-MHz 2-D IIR Beam Filters using ROACH-2 Virtex-6 sx475t FPGA

Vishwa Seneviratne, Arjuna Madanayake and Nilan Udayanga

Abstract

Two-dimensional (2-D) IIR beam filter applications operating in ultra wideband (UWB) radio frequency (RF) range requires hardware capable of handling high speed real-time processing due to its operation bandwidth lies in megahertz or gigahertz range. Two-dimensional IIR beam forming is used mainly for applications such as communications, radars and detection of directional sensing . A systolic architecture is proposed for the real-time implementation of the 2-D IIR beam filter. This the first attempt of evaluating the prospect of practical implementation of such a beam filter capable in ROACH-2 hardware platform which is equipped with a Xilinx Virtex-6 sx475t FPGA chip, widely used in the field of radio astronomy reaching upto 200 MHz operating frequency.

Map Building using Occupancy Grids with Differentiated Occupancy States

Anna Heinemann, Jörg Velten and Anton Kummert

Abstract

For map building purposes it is necessary to distinguish between moving and not moving objects, because moving objects might falsify map matching procedures. This paper presents a new approach of a grid based map building algorithm which represents an extension of occupancy grids. As well as it its archetype, the algorithm can easily be used for 2d or 3d time-dependent map building procedures. The original occupancy grids were extended so that cells which are marked as occupied get further differentiated regarding the motion characteristic of their particular obstacle. An occupied cell can therefore be differentiated in a cell occupied by a dynamic, quasi static or static obstacle. This differentiation might also come in handy regarding object detection or similar algorithms. The presented algorithm was developed and tested using a SICK LMS511 high resolution laser measurement system.

Regular Session: Wave nD Systems

Session chair: Rudolf Rabenstein

Monday 14:30 – 15:50

Stability and Stabilisation of Active Ladder Circuits Modeled in the Form of Two-dimensional (2D) systems

Bartłomiej Sulikowski, Krzysztof Gałkowski and Anton Kummert

Abstract

Electrical ladder circuits can be considered as spatially interconnected systems of regular structure and can be viewed in the form of two dimensional (2D) systems, where one of the indeterminates is time and another number of subsystems building an overall structure. In this paper we develop a new 2D system based method of its stability analysis and stabilizing controller design with the use of Linear Matrix Inequalities (LMI) techniques.

An Unconditionally Stable Finite Difference Scheme Systems Described by Second Order Partial Differential Equations

Petr Augusta, Blazej Cichy, Krzysztof Gałkowski and Eric Rogers

Abstract

An unconditionally stable finite difference scheme for systems whose dynamics are described by a second-order partial differential equation is developed. The scheme is motivated by the well-known Crank-Nicolson discretization which was developed for first-order systems. The stability of the finite-difference scheme is analysed by von Neumann's method. Using the new scheme, a discrete in time and space model of a deformable mirror is derived as the basis for control law design. The convergence of this scheme for various values of the discretization parameters is checked by numerical simulations.

Newton's Method for Modularity-preserving Multidimensional Wave Digital Filters

Tim Schwerdtfeger and Anton Kummert

Abstract

Wave Digital Filter (WDF) theory provides an immediate method to derive robust, stable and real-time capable discretizations of one- or multidimensional prototype networks. However, there are realization constraints for certain types of structures, e.g. the presence of multiple nonlinearities, which result in non-computable implicit relations. A common approach to circumvent this restriction is wave-based modeling with statespace-like structures, where implicit equations are solved iteratively by Newton's method or similar approaches. Unfortunately, these concepts generally give up the modular structure of the WDF, thus the reusability, extendability and topology of the prototype network. In this paper, two multidimensional iteration methods based on Newton's method are proposed that are strictly modular and fit well into the modular concept of WDFs.

Design of a Millimeter-Wave Dish-Antenna based 3-D IIR Radar Digital Velocity Filter

Suranga Handagala, Arjuna Madanayake and Nilan Udayanga

Abstract

The enhancement of radar signatures corresponding to an object traveling in a particular velocity is proposed. The method employs a parabolic dish and focal plane array (FPA) processor together with a network resonant multi-dimensional recursive digital velocity filter. An FPA-fed parabolic dish antenna creates multiple radio frequency (RF) beams. The RF beams can sense simulated moving objects that are illuminated using mm-wave (90 GHz) RF energy. A 3-D IIR digital velocity filter is applied on the simulated radar signals to enhance signatures that are moving at a direction of interest at a given speed while significantly suppressing undesired interfering signals traveling at other velocities and additive Gaussian noise. A dish of diameter 0.5 m and focal length of 30 cm with an FPA with 4096 antenna elements (64×64) arranged in a dense square array is simulated using an electromagnetic field simulator. The resulting electric field intensity profiles are processed to extract the signatures of interest. Simulation results show an average signal to interference improvement of 7 dB with single interference and 6 dB for multiple interference. Proposed method exhibits an average signal to interference and noise ratio (SINR) improvement of 6 dB for input SINR of -15 dB. All results are simulation based. No fabrications have been attempted at this point.

Special Session 2 – Part I: New Trends in Multidimensional System Theory. Celebrating Ettore Fornasini's 70th Birthday

Session chair: Paula Rocha

Tuesday 9:50–11:10

The Fornasini-Marchesini Model – Its Role in the Analysis and Control of Physical Systems

Eric Rogers

Abstract

The variety of signals encountered in the representation of multidimensional systems means that, unlike standard linear time invariant systems, there are many state-space model structures that can be used to represent the dynamics. This paper considers the Fornasini-Marchesini state-space model introduced almost four decades ago, which has been the basis for the derivation of many systems theoretic properties for the multidimensional dynamics it can be used to represent. The purpose of this paper is to highlight more recent control applications areas where this model has been used.

State Representations of Finitely Generated nD Behaviors Over Rings

Eva Zerz

Abstract

Multidimensional linear systems that are finite-dimensional over the coefficient field admit 1D-like state space realizations. We generalize this fact to the case where the base field is replaced by an arbitrary commutative Noetherian ring. It turns out that the concept of "state spaces" has to be replaced by that of "state modules", which are not necessarily free.

Self-boundedness and Self-hiddenness for Implicit Two-dimensional Systems

Lorenzo Ntogramatzidis

Abstract

In this paper we introduce and develop the concepts of self-boundedness and self-hiddenness for implicit two- dimensional systems. The aim of this note is to show that when extending such concepts to a multidimensional setting, a richer structure arises than in the one-dimensional case.

Characterization of nD Systems with Symmetries

Paolo Vettori

Abstract

1D linear systems that exhibit a symmetric behavior were completely characterized in a few papers that F. Fagnani and J. C. Willems wrote in the nineties. However, that theory could be generalized to multidimensional systems only by restricting the class of possible symmetries and considering the specific case of nD systems described by a set of independent equations. It will be shown how to overcome the limitations imposed by the original techniques of the 1D case, developing the theory in its full generality first for nD discrete systems and then extending the results to other types of nD systems – in particular, to systems of partial differential equations.

Special Session 1 – Part II: Recent Advancements in the French Community on Stability and Stabilisation

Session chair: Alban Quadrat

Tuesday 11:40 – 13:00

Computer Algebra Methods for Testing the Structural Stability of Multidimensional Systems

Yacine Bouzidi, Alban Quadrat and Fabrice Rouillier

Abstract

In this paper, we present new computer algebra based methods for testing the structural stability of n-D discrete linear systems (with $n >= 2$). More precisely, starting from the usual stability conditions which resumes to deciding if an hypersurface has points in the unit polydisk, we show that the problem is equivalent to deciding if an algebraic set has real points and use state-of-the-art algorithms for this purpose. Our strategy has been implemented in Maple and its relevance demonstrated through numerous experimentations.

A Constructive Algebraic Analysis Approach to the Equivalence of Multidimensional Linear Systems

Thomas Cluzeau

Abstract

There exist several models for writing the equations of a multidimensional (nD) linear system and equivalence transformations can be used to pass from one representation to another. Within the constructive algebraic analysis approach to nD linear systems theory, this equivalence issue is studied by means of isomorphisms of finitely presented modules. The present paper illustrates this general algebraic analysis approach by focussing on the equivalence problem for two frequently used 2D models, namely the generalized Fornasini-Marchesini models and the Roesser models.

Euler-Bernoulli Beam Flatness Based Control with Constraints

Maria Bekcheva, Luca Greco, Hugues Mounier and Alban Quadrat

Abstract

The control of infinite dimensional systems with constraints is a notoriously difficult task. We consider a general class of linear systems governed by partial differential equations with boundary control. This problem is here treated in a quite natural manner through the freeness property, the analogue of differential flatness for linear systems. Any variable is then expressed as infinite order differential operators applied to the basis components, the analogue of the flat output components. The specialisation of the basis components are functions which are both of Gevrey regularity (in order for the infinite order differential operators to be convergent) and pertaining the flexibility of polynomial splines. An illustration is made through an Euler Bernoulli beam example.

Special Session 2 – Part II: New Trends in Multidimensional System Theory. Celebrating Ettore Fornasini's 70th Birthday

Session chair: Paula Rocha

Wednesday 9:50–11:10

On the Control and Dead-beat Control of 2D Time-relevant Behaviors

Mauro Bisiacco and Maria Elena Valcher

Abstract

Most of the literature about two-dimensional (2D) and multi-dimensional (nD) systems has concentrated on mathematical models for which the two (n, in general) independent variables play the same role. In several engineering applications, however, one of the independent variables is time, and its role is distinguished from that of all the others.
In this talk we provide an overview of the basic results regarding the control and dead-beat control of discrete 2D behaviors, defined on $\mathbb{Z}_+ \times \mathbb{Z}$ and having the time as an independent variable. We first introduce the definitions of time-controllability and of zero-time-controllability, and investigate various (dead-beat) control problems, under different assumptions on what are the measurable variables and what are the target variables. Such problems correspond to different control schemes and hence lead to different necessary and sufficient conditions for the problem solvability.

State Representations of Autonomous 2D Kernel Behaviors using the Fornasini- Marchesini Model

Isabel Brás and Paula Rocha

Abstract

In this talk we recall some of the basic aspects about the representation of autonomous 2D kernel behaviors by means of a state/driving-variable model (SDV) and analyze two distinct ways of obtaining such type of representation. Within the spirit of the behavioral theory these SDV representations have no input nor output variables; they have a similar structure as the Fornasini-Marchesini model, where the driving-variable is an auxiliary variable that plays the role of the input and the output is the whole system variable. A characterization of autonomous 2D kernel behaviors that allow a state representation (a SDV representation without driving-variable) and a way of obtaining a state representation are given. Furthermore, we show how to construct another state representation, which is locally observable, provided that the polynomial representation of the behavior is decomposable into polynomial factors of certain type.

Analysis of Composition Codes

Telma Pinho, Raquel Pinto and Paula Rocha

Abstract

In this talk we consider two-dimensional (2D) convolutional codes. Minimal realizations of convolutional codes via state-space models are an important issue for efficient implementation and construction of good codes. In the 1D case these realizations are completely characterized, but the same does not happen in the 2D case. In a previous contribution, we have characterized minimal realizations by separable Roesser models of 2D convolutional codes of rate $1/n$. However, this problem seems to be very hard for 2D convolutional codes of rate k/n, with $k > 1$. However the problem becomes easier to handle for

composition codes. Such codes are the 2D convolutional codes which admit encoders $G(d_1, d_2)$ that can be decomposed as the product of two 1D encoders, i.e. $G(d_1, d_2) = G_2(d_2)G_1(d_1)$, where $G_1(d_1)$ and $G_2(d_2)$ are full column rank matrices. Minimal realizations of a particular class of composition codes were then obtained. We focus on the right (factor or zero) prime encoders of general composition codes and study their properties. We believe that a deeper knowledge of the prime encoders of a composition code will be an important step into the characterization of the minimal realizations of these codes.

Regular Session: Stability and Stabilisation

Session chair: Eric Rogers

Wednesday 11:40 – 13:00

Stabilization of Nonlinear 2D Fornasini–Marchesini Systems

Pavel Pakshin, Julia Emelianova, Krzysztof Gałkowski and Eric Rogers

Abstract

The paper considers nonlinear 2D systems described by Fornasini–Marchesini and Roesser state-space models. Sufficient conditions for the property of exponential stability are developed in terms of vector Lyapunov functions and a converse stability theorem is proved. A form of passivity, termed exponential passivity, is defined and used, together with a vector storage function, to develop a new control law design algorithm to guarantee exponential stability of the controlled system. As one application, the algorithm is applied to the physically relevant case of systems with nonlinear actuator dynamics.

Application Specific Stability of 3-D Roesser-like Model Realizations

Jörg Velten, Anton Kummert and Krzysztof Gałkowski

Abstract

Stability of multidimensional (k-D) systems is still a challenging field of work. Well known and established stability measures may lead to complex mathematical problems, while simple tests are restricted to special cases of n-D systems. A new stability test for certain discrete 3-D system realizations given in a Roesser-like model description is proposed. This test is suitable for signals bounded with respect to all three coordinate directions, like spatio temporal video image signals. The 3-D system is observed in real operation, i.e. considering a sequence of processing, which leads to a 1-D state space description, allowing for application of a 1-D stability test. Since application of 1-D stability tests to higher dimensional problems is not a completely new approach, main contribution of this paper is the regular and well structured decomposition of a discrete 3-D system description into a classical 1-D state space description.

Meta-heuristics in Multidimensional Systems Stability Study

Eduardo J. Solteiro Pires, Paulo Moura Oliveira and José Tenreiro Machado

Abstract

Multidimensional systems, or n-D systems, are systems having several independent variables. Several topics, in particular stability, of n-D systems ($n > 1$) have attracted the interest of many researchers. The main reason, is because the extension stability theory of 1-D systems to systems with higher dimensions is not straightforward. In this paper, two adopted meta-heuristics algorithms are used for complementing the study of systems stability based on their polynomial characteristics over the variables boundaries. The two meta-heuristics are genetic algorithm and particle swarm optimization due to its popularity. Practical results of both meta-heuristics are compared and the better algorithm highlighted. The results demonstrate that meta- heuristics can be applied in studding multidimensional system stability.

Stabilization of Stochastic 2D Fornasini–Marchesini Systems

Pavel Pakshin, Julia Emelianova, Mikhail Emelianov, Krzysztof Gałkowski and Eric Rogers

Abstract

The paper uses the state-space model setting to consider the stabilization of stochastic nonlinear 2D Fornasini- Marchesini systems, where the properties of stability in the second moment and exponential stability in the mean square (ESMS) are defined and sufficient conditions for their existence established. In the case of ESMS a converse theorem is also established. The property of stochastic dissipativity in the second moment is introduced and a particular case of this property, termed passivity in the mean square, is used, together with a vector storage function, to develop a new method for control law design. Two practically motivated examples are given to demonstrate the application of the new results.

Regular Session: Vision

Session chair: Anton Kummert

Wednesday 16:20 – 17:50

Classification of Ascending Steps and Stairs using Time-of-Flight Sensor Data

Carsten Stahlschmidt, Alexandros Gavriilidis and Anton Kummert

Abstract

This paper proposes an aspect of a real-time system using a low-resolution Time-of-Flight (ToF) camera to analyse human-made environments in order to verify the presence of ascending steps or stairs. Our system is intended to assist visually impaired people by providing acoustic information about the scene in front of the ToF camera which is fixed to a mobile vehicle (rollator). Detailed instructions are provided to the user about potentially hazardous situations. This paper in particular deals with the classification of ascending steps in 3D point clouds in order to enhance the ability of the system to help the visually impaired understand the environment and help prevent collisions.

Evaluation of Pedestrian Detection Fusion and Localization Based on the Idea of Car-To-X Communication

Alexandros Gavriilidis, Carsten Stahlschmidt, Jörg Velten and Anton Kummert

Abstract

Pedestrian safety applications for urban environments, e.g. observation of intersections or crosswalks for pedestrians, are a growing research area. This paper is focused on the fusion of detected pedestrians from different viewing angles, especially from a surveillance system and from a moving car. Therefore, a combination of the available information inside of a generated world map, which is based on the global positioning system (GPS), is presented. The model for transforming detections with assumed uncertainties into the world map, and an attempt to combine separate independent single detections from different views to a unique one are results of the paper. Besides the combination of information, an evaluation of the detection accuracy of a surveillance system and a monocular object detection driver assistance system is presented. This evaluation discloses drawbacks as well as benefits of an information mapping from different viewing angles into a global world map.

Orientation and Positioning with Inertial Sensors for Walking Frame Guidance

Kathrin Kalischewski, Daniel Wagner, Jörg Velten and Anton Kummert

Abstract

Mobility for blind or partially blind with walking disability is hard to realize. A walking frame assists in movement, but the orientation and positioning for people with restricted visual ability without external help is nearly impossible. They also have trouble with object recognition to avoid collisions and prevent injuries. Therefore there is the need to assist people with restricted moving and seeing ability, so that they can move unrestricted. The application of the

Microsoft Kinect is an effective and low cost method to lead people through the environment with detailed depth information offered by an infrared camera. Additionally with the help of inertial sensors for navigation an imaging of the surrounding object and obstacle recognition is possible. In this paper orientation and positioning of a walking frame with accelerometer and gyroscope is explained and how these data supports obstacle recognition with the Kinect. The results and opportunities for further usage are presented.

Detection of Ascending and Descending Stairways by Surface Normal Vectors

Daniel Wagner, Kathrin Kalischewski, Jörg Velten and Anton Kummert

Abstract

Persons with walking frames are often limited in their sight and they are depending on assistance. To give them the possibility to move free and autonomous in their environment a Kinect is used to observe the scene in front of the walking frame. Obstacles should be recognized. Especially stairways represent a high risk of injury, if a collapse occurs. For stairway recognition an algorithm estimates normal vectors by using a covariance matrix and this makes it possible to segment the point cloud data. The calculation of surface normal vectors of these regions helps to detect ascending and descending stairways.

Censorship of Video Images with Adaptive Reconstruction based on Spectral Domain Watermarking

Thomas Sablik, Jörg Velten and Anton Kummert

Abstract

Censorship of video images has become an important field of science nowadays. Multimedia files often contain sensitive content that should be unseen by human observer. Therefor a novel system for censorship of video images based on spectral domain watermarking is described in the present paper. Faces are detected by face detection algorithms and embedded as watermarks into the images. Then these areas are blurred to protect privacy. The whole MJPEG video is also embedded as watermark to protect against tampering. Adaptive reconstruction allows low quality reconstruction of tampered areas and high quality reconstruction of protected faces.

Regular Session: Theoretical Advances in 2D Systems

Session chair: Maria Elena Valcher

Wednesday 16:20 –17:20

On some 2D Integro-differential Control Problem

Marek Majewski and Andrzej Skowron

Abstract

In this paper an integro-differential problem with a mixed partial derivative and a functional parameter is considered. A theorem on the existence and uniqueness of solutionis proved. Moreover, we prove that the problem is sensitive, i.e. the dependence of solution on parameter is a differentiable function. The proof of the main result is based on a theorem on diffeomorphism. The problem under consideration can be viewed as a generalization of classical integro-differential problem of Volterra type towards $2D$ systems.

Series Concatenation of 2D Convolutional Codes

Joan-Josep Climent, Diego Napp, Raquel Pinto and Rita Simões,

Abstract

In this paper we study two-dimensional (2D) convolutional codes which are obtained from series concatenation of two 2D convolutional codes. In this preliminary work we confine ourselves to dealing with finite-support 2D convolutional codes and make use of the so-called Fornasini-Marchesini input-state-output (ISO) model representations. In particular, we show that the interconnection in series of two 2D convolutional codes is again a 2D convolutional code and we explicitly compute an ISO representation of the code. Within these ISO representations we study when the structural properties of reachability and observability of the two given ISO representations carry over to the resulting 2D convolutional code.

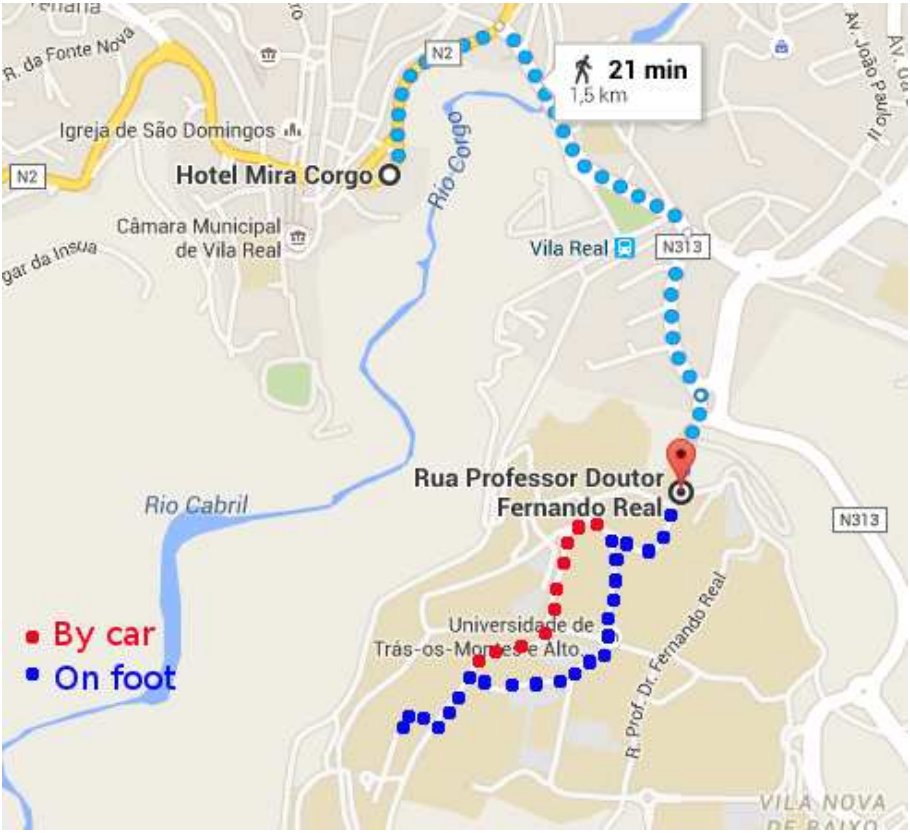
Nash Equilibrium with Wave Dynamics and Boundary Control

Teresa Paula Azevedo Perdicoúlis, Gerhard Jank and Paulo Lopes dos Santos

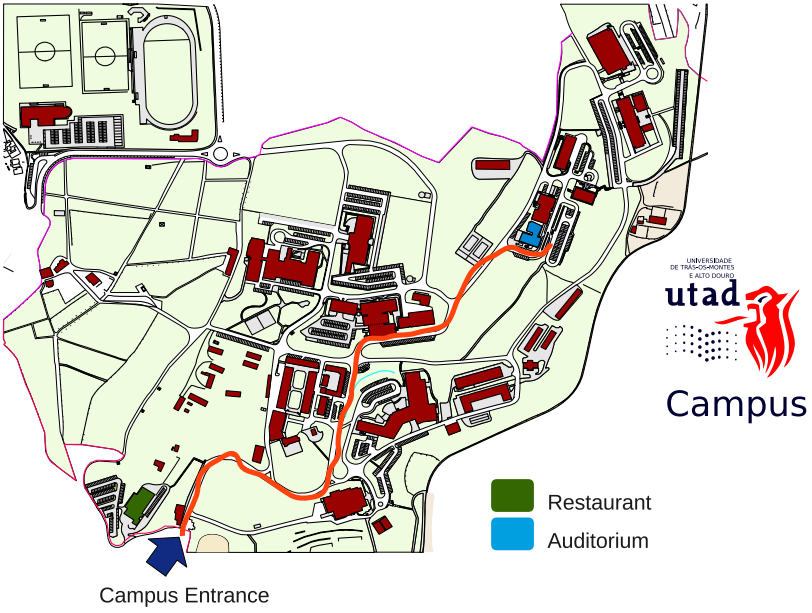
Abstract

In this paper, the gas dynamics within the pipelines is written as a wave repetitive process, and modify it in a way that the dynamics is influenced by p decision makers, namely the boundary conditions. We obtain sufficient criteria for the existence of boundary equilibrium controls as well as controllability of the different agents and observability of the system when this is steered through initial and boundary data. From the point of view of some applications it seems to make sense to consider boundary data controls, e.g. in high pressure gas networks management.

How to Reach the Conference Venue



UTAD Campus



The conference takes place in Auditorium of Florestal Building (GPS: 41°17'08.9"N 7°44'36.9"W).

The Restaurant is located at the entrance of UTAD Campus (left side of the arrow).

Relevant Information

Welcome Drink

The welcome drink is held at Miracorgo Hotel.

Social Program

Tour to *Quinta das Carvalhas*: a bus is waiting in front of *Ciências Florestais* building (conference building) at 3:30pm.

Conference Dinner

The conference dinner is held at Miracorgo Hotel at 8:30pm.

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