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Nikos E. Mastorakis
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Recent Advances in Electrical Engineering

- Proceedings of the 13th International Conference on Instrumentation, Measurement, Circuits and Systems (IMCAS '14)
- Proceedings of the 2nd International Conference on Power Engineering, Energy and Electrical Drives (PEED '14)
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Mihai Timis                     Cledson Akio Sakurai
Yi-Chao Wu                      Francesco Zirilli
# Table of Contents

**Plenary Lecture 1: On Ulam's Type Stability**  
Janusz Brzdek

10

**Stability and Hyperstability of Some Functional Equation**  
Magdalena Piszczek, Joanna Szczawiska

13

**Properties of Different Nonlinear Integrals of Multifunctions**  
Cristina Stamate, Anca Croitoru

16

**Design of Analog-Front End for Sensorless BLDC Motor Driver**  
Kichang Jang, Chulkyu Park, Jungryul Choi, Kwanseok Jung, Seungheun Song, Subin Kim, Joongho Choi

21

**The Use of MEMS Accelerometers for Control of a Small Unmanned Underwater Vehicle**  
Bogdan Żak, Stanisław Hożyń

26

**Wide Load Range High Efficiency Design Consideration of a Self-Driven Synchronous Rectified Phase-Shifted Full-Bridge Converter for Data Center Application**  
Sevilay Cetin

33

**Effects of Mixed Faults on the Stator Current Spectrum of the Induction Machine**  
Kaikaa Mohamed Yazid

44

**Multidimensional Functional Similarity Measure for Image Quality Assessment**  
Yun Fah Chang, Omar Mohd Rijal, Syed Abdul Rahman Abu Bakar

52

**Control of Nonlinear Instabilities in a Higher Order Current-Mode Controlled Converter**  
Ibrahim Daho, Otman Imrayed

62

**Computer Aided Design and Transient Finite Elements Analysis of Induction Motor**  
Huseyin Tarik Duru

70

**Optimal Constrained Control Allocation for Underwater Robotic Vehicle - Comparison of Algorithms**  
Jerzy Garus, Ryszard Studanski, Bogdan Żak

77

**Enhanced Clustering Method using 3D Laser Range Data for an Autonomous Vehicle**  
Kuk Cho, Seungho Baeg, Sangdeok Park

82

**New Generation Ion-Conducting Electrolytes Based On Silsesquioxane Derivatives**  
Asuman C. Kucuk, Jun Matsui, Takuji Miyashita

88

**Study of a Wind/PV/Battery Hybrid System at Plaka in Greece**  
J. G. Fantidis, D. V. Bandekas, N. Vordos, Ch. Fylaktakidis, J. W. Nolan

93
<table>
<thead>
<tr>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Urbanization Analysis through Remote Sensing and GIS in Kuala Lumpur, Manila and Singapore Cities</strong></td>
<td>99</td>
</tr>
<tr>
<td>Mukesh Singh Boori, Maik Netzband, Vít Voženílek, Komal Choudhary</td>
<td></td>
</tr>
<tr>
<td><strong>Comparison of Regional Photovoltaic Energy Production: Marmara Region</strong></td>
<td>111</td>
</tr>
<tr>
<td>Şafak Sağlam, Bülent Oral, Sertaç Görgülü</td>
<td></td>
</tr>
<tr>
<td><strong>A Low-Power Sigma-Delta Modulator with Adaptive Slew-Enhancement Technique</strong></td>
<td>117</td>
</tr>
<tr>
<td>Chulkyu Park, Kichang Jang, Jungryul Choi, Jongkeun Hwang, Hyojae Kim, Joongho Choi</td>
<td></td>
</tr>
<tr>
<td><strong>The Transition from Smooth to Nonsmooth Period-Doubling Bifurcation in Boost Converter</strong></td>
<td>121</td>
</tr>
<tr>
<td>Otman Imrayed, Ibrahim Daho, H. M. Amreiz</td>
<td></td>
</tr>
<tr>
<td><strong>On the Multi–Parameter Optimization of CNC Plasma-Arc Cutting Process Quality Indicators using Taguchi Design of Experiments</strong></td>
<td>128</td>
</tr>
<tr>
<td>J. Kechagias, P. Stavropoulos, S. Maropoulos, K. Salonitis</td>
<td></td>
</tr>
<tr>
<td><strong>Inverse Electrocardiography Using Reduced Lead-Set by TTLs and LTTLS Regularization Algorithms</strong></td>
<td>134</td>
</tr>
<tr>
<td>Fourough Gharbalchi, Yesim Serinagaoglu Dogrusoz, Gerhard Wilhelm Weber</td>
<td></td>
</tr>
<tr>
<td><strong>Preventive Maintenance Optimization in Wind Power System Using Gravitational Search Algorithm</strong></td>
<td>141</td>
</tr>
<tr>
<td>R. Meziane, M. Amara, S. Boufala, H. Amar</td>
<td></td>
</tr>
<tr>
<td><strong>Deformation Vector Differences between Two Dimensional (2D) and Three Dimensional (3D) Deformation Analysis</strong></td>
<td>152</td>
</tr>
<tr>
<td>H. Hakan Denli, Seda Cetin</td>
<td></td>
</tr>
<tr>
<td><strong>Comparison of Frequency-Warped Filter Banks in relation to Robust Features for Speaker Identification</strong></td>
<td>157</td>
</tr>
<tr>
<td>Sharada V. Chougule, Mahesh S. Chavan</td>
<td></td>
</tr>
<tr>
<td><strong>Area-Efficient Look-Up Tables for Semi-Randomly Accessible Functions</strong></td>
<td>171</td>
</tr>
<tr>
<td>Hasan Ünlü, Mehmet Akif Özkan, H. Fatih Ugurdag, Eşref Adali</td>
<td></td>
</tr>
<tr>
<td><strong>Power Conscience Solution for User’s Energy-Consumption Saving in Smart Grids</strong></td>
<td>175</td>
</tr>
<tr>
<td>Adel Bouallegue</td>
<td></td>
</tr>
<tr>
<td><strong>Evaluation of Spot Welding Electrodes in Automotive Industry in Real Time using Digital Image Processing and Image Segmentation Techniques</strong></td>
<td>181</td>
</tr>
<tr>
<td>Abdulwanis Abdulhadi, Ahmed Ahtaiba</td>
<td></td>
</tr>
<tr>
<td><strong>Measuring the Pulse Rate by Using Web Cam</strong></td>
<td>192</td>
</tr>
<tr>
<td>R. Archana , M. Lakshmi Ravi Teja</td>
<td></td>
</tr>
<tr>
<td><strong>Self-Driven Phase Shifted Full Bridge Converter for Telecom Applications</strong></td>
<td>196</td>
</tr>
<tr>
<td>Sevilay Cetin</td>
<td></td>
</tr>
</tbody>
</table>
Decentralized Observer-Based Robust Model Predictive Control for a Class of Distributed Networked Systems
S. Vahid Naghavi, A. A Safavi, S. Pourdehi

Conversion of the METCM into the METEO-11
Karel Šilinger, Martin Blaha, Ladislav Potužák

A Comparative Study for Handwritten Sanskrit Character Recognition Using BPNN and RBF Networks
R. Dineshkumar, J. Suganthi

A Comparison between the Raw Experimental AFM Image and the Restored AFM Image that was Produced Using the Impulse Response Technique at Different Scanning Speeds
Ahmed Ahtaiba, Abdulwanis Abdulhadi, Mohammed Elmahdi

High Performance Compact FinFET Based Inductive Boost Converter
Mohd. Yasir, Mohd. Hasan

Authors Index
Abstract:

Quite often (e.g., in applications), we have to do with functions that satisfy some equations only approximately. There arises a natural question what errors we commit when we replace such functions by the exact solutions to those equations. Some tools to evaluate them are provided within the theory of the Ulam (also Hyers-Ulam) type stability.

The issue of Ulam’s type stability of (first, functional, but next also difference, differential and integral) equations has been of a very popular subject of investigations for the last nearly fifty years (see, e.g., [3, 8, 9, 10]). The main motivation for it was given by S.M. Ulam in 1940. The following definition somehow describes the main ideas of such stability notion for equations in $n$ variables ($\mathbb{R}_+$ stands for the set of nonnegative reals).

**Definition 1.** Let $A$ be a nonempty set, $(X,d)$ be a metric space, $C \subseteq X^A$ a nonempty, $T$ map $C$ into $X^A$, and $\mathcal{F}_1, \mathcal{F}_2$ map a nonempty $D \subseteq X^A$ into $X^{A^n}$. We say that the equation $F_1\varphi(x_1, \ldots, x_n) = F_2\varphi(x_1, \ldots, x_n)$ is $T$-stable provided for every $\varepsilon \in C$ and $\varphi_0 \in D$ with

$$d(F_1\varphi_0(x_1, \ldots, x_n), F_2\varphi_0(x_1, \ldots, x_n)) \leq \varepsilon(x_1, \ldots, x_n), \quad x_1, \ldots, x_n \in A,$$

there is a solution $\varphi \in D$ of equation (1) such that $d(\varphi(x), \varphi_0(x)) \leq T\varepsilon(x)$ for $x \in A$.

The next two theorems contain examples of some results on stability of the additive Cauchy equation (see [3]) and of a linear difference equation of higher order (see [7]).

**Theorem 1.** Let $E_1$ and $E_2$ be two normed spaces, $c \geq 0$ and $p \neq 1$ be fixed real numbers. Let $f : E_1 \to E_2$ be such that

$$\|f(x + y) - f(x) - f(y)\| \leq c(\|x\|^p + \|y\|^p), \quad x, y \in E_1 \setminus \{0\}.$$ 

If $p < 0$, then $f$ is additive (i.e., $f(x + y) = f(x) + f(y)$ for $x, y \in E_1$). If $p \geq 0$ and $E_2$ is complete, then there is a unique additive $T : E_1 \to E_2$ with

$$\|f(x) - T(x)\| \leq \frac{c\|x\|^p}{2^p - 1}, \quad x \in E_1 \setminus \{0\}.$$

**Theorem 2.** Let $T$ be either $\mathbb{N}$ or $\mathbb{Z}$, $X$ be a Banach space over $F \in \{\mathbb{R}, \mathbb{C}\}$, $(b_n)_{n \in T}$ be a sequence in $X$, $a_1, \ldots, a_m \in F$, $\delta > 0$ and $r_1, \ldots, r_m \in \mathbb{C}$ be the roots of the characteristic equation of the difference equation

$$x_{n+m} = a_1x_{n+m-1} + \cdots + a_mx_n + b_n, \quad n \in T.$$ (2)
Suppose that $|r_i| \neq 1$ for $i = 1, \ldots, m$ and $(y_n)_{n \in T}$ is a sequence in $X$ with
\[
\|y_{n+1} + a_1 y_{n+1} \cdots + a_m y_n - b_n\| \leq \delta, \quad n \in T.
\]
Then there exists a sequence $(x_n)_{n \in T}$ in $X$ such that (2) holds and
\[
\|y_n - x_n\| \leq \frac{\delta}{|1 - r_1| \cdots |1 - r_m|}, \quad n \in T.
\]

The lecture contains some basic motivations, definitions and results connected with the notion of the Ulam (but also the Hyers-Ulam) type stability. A general method will also be presented for investigations of that stability, e.g., of the following linear (difference, differential, functional) equations of higher orders:
\[
\begin{align*}
&b_m \varphi(n + m) + b_{m-1} \varphi(n + m - 1) + \cdots + b_1 \varphi(n + 1) + b_0 \varphi(n) = G(n), \\
&b_m \varphi^{(m)}(z) + b_{m-1} \varphi^{(m-1)}(z) + \cdots + b_1 \varphi'(z) + b_0 \varphi(z) = G(z), \\
&b_m \varphi^{(m)}(z) + b_{m-1} \varphi^{(m-1)}(z) + \cdots + b_1 \varphi'(z) + b_0 \varphi(z) = G(z).
\end{align*}
\]
It works for analogous integral equations, as well. In many cases, functions satisfying such equations approximately generate the exact solutions to them (see, e.g., [2]). That method can be described in the terms of fixed points in suitable function spaces (for related results see, e.g., [1, 5, 6]). Some examples of simple applications of it are provided.

References

Brief Biography of the Speaker: Present permanent employment: Department of Mathematics, Pedagogical University, Kraków, Poland; position of professor 1983 – Master of Science in Mathematics, Jagiellonian University, Kraków, Poland 1991 – PhD in Mathematics 2000 – Habilitation in Mathematics Major research interests: functional equations and inequalities with their applications, Ulam’s type stability (e.g., of difference, differential, functional, integral and operator equations), real and functional analysis, fixed point theory. Author of over 100 papers that are already printed or accepted for publication. Chairman of the Scientific Committee of the series of conferences: International Conference on Functional Equations and Inequalities (ICFEI) (http://uatacz.up.krakow.pl/icfei/15ICFEI/) Chairman of the Organizing Committees of 10th (2005), 11th (2006), 12th (2008), 13th (2009), 14th (2011), 15th (2013), and 16th (2015) ICFEIs (http://uatacz.up.krakow.pl/icfei/15ICFEI/prev.php) Chairman of the Scientific and Organizing Committees of the conference: Conference on Ulam’s Type Stability, Ustron (Poland), June 2-6, 2014 (http://cuts.up.krakow.pl/) Member of the Program or Scientific Committees of several other international conferences Editor (jointly with Th.M. Rassias) of the monograph Functional Equations in Mathematical Analysis (nearly 750 pages; collection of 47 papers of 67 authors), volume 52 (2013) of Springer Optimization and Its Applications series, dedicated to the 100th anniversary of S.M. Ulam Lead Editor of Banach Center Publications volume 99 (2013) titled: Recent Developments in Functional Equations and Inequalities. Selected Topics Lead Guest Editor of Abstract and Applied Analysis special issues: Ulam’s Type Stability.
(http://www.hindawi.com/journals/aaa/type.stability/) in the years 2012, 2013
Lead Guest Editor of Journal of Function Spaces (formerly: Journal of Function Spaces and Applications)
special issue: Ulam’s Type Stability and Fixed Points Methods
(http://www.hindawi.com/journals/fs/si/329604/cfp/)
Lead Guest Editor of Discrete Dynamics in Nature and Society special issue: Approximate and Iterative
Methods (http://www.hindawi.com/journals/ddns/si/473241/)
Supervisor of four promoted PhD students.
Editor of several international journals.