Novel Algorithms and Techniques in Telecommunications, Automation and Industrial Electronics
Novel Algorithms and Techniques in Telecommunications, Automation and Industrial Electronics

Edited by
Tarek Sobh
Khaled Elleithy
Ausif Mahmood
Mohammad A. Karim

Springer
## Contents

| Preface | xiii |
| Acknowledgements | xv |

1. Kernel Locally Linear Embedding Algorithm for Quality Control.................................1  
   Thrasioulovos Tsagaroulis, A. Ben Hamza

2. A New Method for Synchronization and Control of the Chen Chaotic System..........................7  
   Afshin Izadian et al.

3. The Intra Prediction in H.264..................................................................................................11  
   Ahmad Khalil Khan, Habibullah Jamal

   A. Montoya et al.

5. Inter-Agent Communication Adaptations for Power Network Processes Simulation...............22  
   Miroslav Prýmek, Aleš Horák

6. DC Motor Monitoring and Control System ..............................................................................26  
   Andrei Cozma

7. Web-Based Tele-Operated Control System of a Robotic Vehicle ........................................32  
   Aneesh N. Chand

8. Number Plate Recognition Using Analytical Fourier Mellin Transform................................37  
   Anshul Mittal, Mayank Sharma

9. Middleware-Based Kalman Filter Design for a Driver’s Aid System...................................43  
   Wenwei Hou et al.

10. Improving Neural Network Performances – Training with Negative Examples..................49  
    Cosmin Cernăzanu-Grăvan, Ştefan Holban

    Giuseppe Della Penna et al.

12. An Artificial Immune System Based Multi-Agent Robotic Cooperation................................60  
    Dioubate Mamady et al.

    Olga Ormandjieva, Emil Vassey

14. A Novel Control System for a Direct Drive Linear Permanent Magnet Actuator with Intrinsic Position Hold..........................................................77  
    Evgueni Sliva et al.
<table>
<thead>
<tr>
<th>No.</th>
<th>Title</th>
<th>Authors</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>15.</td>
<td>Characterizing the Exact Collision Course in the Plane for Mobile Robotics Application</td>
<td>K. Bendjilali et al.</td>
<td>83</td>
</tr>
<tr>
<td>16.</td>
<td>Acquisition System for Monitoring Vibrations</td>
<td>Grofu Florin et al.</td>
<td>89</td>
</tr>
<tr>
<td>17.</td>
<td>Object-of-Interest Selection for Model-Based 3D Pose Tracking with Background Clutter</td>
<td>Hans de Ruiter et al.</td>
<td>93</td>
</tr>
<tr>
<td>19.</td>
<td>Design and Control of an Omni-Directional Mobile Robot</td>
<td>Ioan Doroftei et al.</td>
<td>105</td>
</tr>
<tr>
<td>20.</td>
<td>Preventing Pole-Zero Cancellation for Improved Input Disturbance Rejection in Iterative Feedback Tuning Systems</td>
<td>J. Sikaundi, M. Braae</td>
<td>111</td>
</tr>
<tr>
<td>21.</td>
<td>General Inverse Neural Current Control for Buck Converter</td>
<td>José Guillermo Guarnizo M. et al.</td>
<td>117</td>
</tr>
<tr>
<td>23.</td>
<td>Robust Control PID for Time Delays Systems</td>
<td>Laura E. Muñoz et al.</td>
<td>128</td>
</tr>
<tr>
<td>24.</td>
<td>Wavelets vs Shape-Based Approaches for Image Indexing and Retrieval</td>
<td>L. Flores-Pulido et al.</td>
<td>134</td>
</tr>
<tr>
<td>25.</td>
<td>Formal Specification and Simulation of the Robot Perceptual System</td>
<td>M. Yassine Belkhouche, Boumediene Belkhouche</td>
<td>140</td>
</tr>
<tr>
<td>26.</td>
<td>Enhancing Diagnosis Ability for Embedded Electronic Systems Using Co-Modeling</td>
<td>Manel KHLIF, Mohamed SHAWKY</td>
<td>144</td>
</tr>
<tr>
<td>27.</td>
<td>Development Environment Using FPGA for Domotics Applications Based on X10 Technology</td>
<td>Manuel D. Cruz et al.</td>
<td>150</td>
</tr>
<tr>
<td>28.</td>
<td>Robustness of a Robot Control Scheme for Liquid Transfer</td>
<td>M. P. Tzamtzi, F. N. Koumboulis</td>
<td>154</td>
</tr>
<tr>
<td>30.</td>
<td>Use of a Connection Model for Dynamic Systems</td>
<td>M. Braae</td>
<td>168</td>
</tr>
</tbody>
</table>
32. Tracking Performance of an Identical Master-Slave Teleoperation System Under Variable Time Delays .......................................................... Mehmet Ismet Can Dede, Sabri Tosunoglu

33. New Concept in Optimizing Manipulability Index of Serial Manipulators, Using SVD Method........ Mohammed Magdy et al.

34. Region of Interest Labeling of Ultrasound Abdominal Images Using Hausdorff Distance ................. Naveen Aggarwal et al.

35. Control of Electric Motor Parameters on the Basis of QR- Decomposition Technique .................. First A. Viktor Melnikov et al.


37. A Peer-to-Peer Collaboration Framework for Multi-Sensor Data Fusion ........................................... Panho Lee et al.

38. Software Implementation of Explicit DMC Algorithm with Improved Dependability .................... Piotr Gawkowski et al.


40. Various Methods of Economical Load Distribution in Power Plant Units in Comparison to Neural Networks Method ........................................ Mohammad Taghi Ameli et al.

41. Automated Surveillance of Intruders at US Borders .............................................................. Kalyan Marneni, Sreela Sasi

42. PDFF and $H^\infty$ Controller Design for PMSM Drive ................................................................. Stone Cheng et al.


45. Data Processing for Mapping in Mobile Robotics ................................................................. Tomas Neuzil, Ondrej Jez


47. Reliability Model for MEMS Accelerometers ........................................................................ Xingguo Xiong et al.

48. Diagram, Dynamic Geometry and Sangaku ........................................................................... Yoshiteru Ishida, Masayuki Fujisawa
<table>
<thead>
<tr>
<th>No.</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>49.</td>
<td>A Modeling Technique for Execution and Simulation of Discrete Automation</td>
<td>273</td>
</tr>
<tr>
<td></td>
<td>Yuval Cohen</td>
<td></td>
</tr>
<tr>
<td>50.</td>
<td>Using DES in a Modified Design to Keep it from Oblivion</td>
<td>278</td>
</tr>
<tr>
<td></td>
<td>Abdelshakour Abuzneid et al.</td>
<td></td>
</tr>
<tr>
<td>51.</td>
<td>One-Time Password Authentication with Infinite Hash Chains</td>
<td>283</td>
</tr>
<tr>
<td></td>
<td>Alexander G. Chefranov</td>
<td></td>
</tr>
<tr>
<td>52.</td>
<td>Estimation of OFDM Time-Varying Fading Channels Based on Two-Cross-Coupled Kalman Filters</td>
<td>287</td>
</tr>
<tr>
<td></td>
<td>Ali Jamoos et al.</td>
<td></td>
</tr>
<tr>
<td>53.</td>
<td>EcoLocate: A Heterogeneous Wireless Network System for Wildlife Tracking</td>
<td>293</td>
</tr>
<tr>
<td></td>
<td>Andrew C. Markham, Andrew J. Wilkinson</td>
<td></td>
</tr>
<tr>
<td>54.</td>
<td>Enhancement of Throughput in 802.15.4 MAC Layer Using the Principle of Circularity</td>
<td>299</td>
</tr>
<tr>
<td></td>
<td>R Bhakthavathsalam</td>
<td></td>
</tr>
<tr>
<td>55.</td>
<td>Wireless LAN Security Mechanisms at the Enterprise and Home Level</td>
<td>305</td>
</tr>
<tr>
<td></td>
<td>Bogdan Crainicu</td>
<td></td>
</tr>
<tr>
<td>56.</td>
<td>Synchronization Solution for the TDSC-UWB Detection Method</td>
<td>311</td>
</tr>
<tr>
<td></td>
<td>Charbel Saber et al.</td>
<td></td>
</tr>
<tr>
<td>57.</td>
<td>An Efficient In-Network Event Detection Algorithm for Wireless Sensor Nodes</td>
<td>317</td>
</tr>
<tr>
<td></td>
<td>Chirakkal V. Easwaran</td>
<td></td>
</tr>
<tr>
<td>58.</td>
<td>Performance Evaluation of Distance Vector Routing Protocol on a Wireless Circular Model</td>
<td>323</td>
</tr>
<tr>
<td></td>
<td>D. C. Vasiliadis et al.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Eman Abdelfattah, Guinshin Liu</td>
<td></td>
</tr>
<tr>
<td>60.</td>
<td>Optimizing Bandwidth Usage and Response Time Using Lightweight Agents on Data Communication Network</td>
<td>335</td>
</tr>
<tr>
<td></td>
<td>E.A. Olajubu et al.</td>
<td></td>
</tr>
<tr>
<td>61.</td>
<td>Location Information Discovery for IP Telephony</td>
<td>341</td>
</tr>
<tr>
<td></td>
<td>Leon Stringer et al.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Geneflides Laureno da Silva, Raimir Holanda Filho</td>
<td></td>
</tr>
<tr>
<td></td>
<td>G M Shafiullah et al.</td>
<td></td>
</tr>
<tr>
<td>64.</td>
<td>Stepping-Stone Intrusion Detection Using Neural Networks Approach</td>
<td>358</td>
</tr>
<tr>
<td></td>
<td>Han-Ching Wu, Shou-Hsuan Stephen Huang</td>
<td></td>
</tr>
<tr>
<td>65.</td>
<td>Packet Fluctuation Approach for Stepping-Stone Detection</td>
<td>364</td>
</tr>
<tr>
<td></td>
<td>Han-Ching Wu, Shou-Hsuan Stephen Huang</td>
<td></td>
</tr>
<tr>
<td>Article Number</td>
<td>Title</td>
<td>Authors</td>
</tr>
<tr>
<td>----------------</td>
<td>----------------------------------------------------------------------</td>
<td>----------------------------------------------</td>
</tr>
<tr>
<td>66</td>
<td>Using Mobile Telephone as an Operator Independent, Secure Micro-Payment Tool</td>
<td>Hasan AMCA, Erbug CELEBí</td>
</tr>
<tr>
<td>67</td>
<td>Multiplexing Overlays on Bluetooth</td>
<td>Abdelshakour Abuzneid et al.</td>
</tr>
<tr>
<td>68</td>
<td>The Problem of Predicting the Data Transmitting Delay in the Network with the Self-Similar Nature of Traffic, for the Purpose of Improving the Real-Time Conferencing</td>
<td>I. Sychev et al.</td>
</tr>
<tr>
<td>69</td>
<td>Guidelines for Constructing Robust Discrete-Time Computer Network Simulations</td>
<td>John Richter, Barry Irwin</td>
</tr>
<tr>
<td>70</td>
<td>A Study on Enhanced Multipath Routing Protocol in Hybrid Wireless Mesh Network</td>
<td>JoonYoung Cho et al.</td>
</tr>
<tr>
<td>71</td>
<td>Pseudorandom Number Generation Using Cellular Automata</td>
<td>Byung-Heon Kang et al.</td>
</tr>
<tr>
<td>72</td>
<td>An Efficient Estimation Algorithm for MIMO OFDM System Using Turbo Codes</td>
<td>Khalida Noori et al.</td>
</tr>
<tr>
<td>73</td>
<td>Dynamic Rate Control Algorithm for Streaming Media Over Wireless Channel</td>
<td>Kostas. E. Psannis</td>
</tr>
<tr>
<td>74</td>
<td>Interactive Compression Algorithms for Streaming Media Over High Speed Networks</td>
<td>Kostas. E. Psannis</td>
</tr>
<tr>
<td>75</td>
<td>The Adaptive Potential of Reconfigurable MEMS in MIMO Antenna Technology</td>
<td>Ligia Chira Cremene, Nicolae Crisan</td>
</tr>
<tr>
<td>76</td>
<td>Voice, Video and Data Transmission Over Electrical Power Supply Networks. PLC (Power Line Communications): A Last Mile Alternative for Venezuela</td>
<td>Luis R. Madera B.</td>
</tr>
<tr>
<td>77</td>
<td>Design and Analysis of Optical Interconnection Networks for a Dataflow Parallel Computer</td>
<td>João E. M. Perea Martins, Marcos A. Cavenaghi</td>
</tr>
<tr>
<td>78</td>
<td>Tracking of Mobile Nodes in Sensor Networks</td>
<td>Daniel Froß et al.</td>
</tr>
<tr>
<td>79</td>
<td>IP Based Mobility Management for Next Generation Wireless Networks</td>
<td>Md. Akbar Hossain, Khan Md. Rezaul Hoque</td>
</tr>
<tr>
<td>80</td>
<td>Addressing Spam at the Systems-Level Through a Peered Overlay Network-Based Approach</td>
<td>Michael Horie, Stephen W. Neville</td>
</tr>
<tr>
<td>81</td>
<td>A Step Towards an Autonomous Tuning Engine Design for Self-Protection and Self-Configuration</td>
<td>Nadir Zamin Khan et al.</td>
</tr>
<tr>
<td>82</td>
<td>Enhancing Network Performance with TCP Configuration</td>
<td>Napat Sra-ium, Kobchai Dejhan</td>
</tr>
</tbody>
</table>
83. Hybrid Scheme by Using Linear Feedback Shift Registers & RSA Security ........................................463
    P.R. Suri, Priti Puri

84. Analysis of Optical WDM Network Topologies with Application of LRWC Under Symmetric Erlang –C Traffic.................................................................468
    Rahul Kundu, V. K. Chaubey

85. Estimation of Radar Alignment Parameters in Multi Sensor Data Fusion Systems Using MLE Technique..........................................................................................474
    SGK Murthy et al.

86. Pre-amp EDFA ASE Noise Minimization for Optical Receiver Transmission Performance Optimization........................................................................................................480
    Akram Abu-aisheh, Saeid Moslehpour

87. Light Weight Cryptography and Applications ......................................................................484
    Sandeep Sadanandan, Rajyalakshmi Mahalingam

88. Energy Dependent Connection Availability Model for Ad Hoc Networks..................................489
    Dimitar Trajanov et al.

89. Trust Management in Ad Hoc Network for Secure DSR Routing ............................................495
    Subhrabrata Choudhury et al.

90. Investigating the Effects of Encoder Schemes, WFQ & SAD on VoIP QoS .....................................501
    Ajay Shrestha et al.

91. A Novel Approach for Creating Consistent Trust and Cooperation (CTC) among Mobile Nodes of Ad Hoc Network...........................................................................506
    Khurram S. Rajput et al.

92. Bandwidth Problem in High Performance Packet Switching Network........................................512
    Syed S. Rizvi et al.

93. An Efficient Scheme for Traffic Management in ATM Networks..............................................516
    Syed S. Rizvi et al.

94. Use of Self-Adaptive Methodology in Wireless Sensor Networks for Reducing the Energy Consumption.................................................................519
    Syed S. Rizvi et al.

95. Reducing Malicious Behavior of Mobile Nodes in Ad Hoc Networks........................................526
    Syed S. Rizvi et al.

96. Application and Evaluation of the LDPC Codes for the Next Generation Communication Systems.....532
    Teodor B. Iliev et al.

    Thomas Mundt

98. A System Architecture for SIP/IMS-Based Multimedia Services.............................................543
    Xianghan Zheng et al.
99. Further Improvements to the Kerberos Timed Authentication Protocol .............................................549
    Y. Kirsal, O. Gemikonakli

100. Self-Repairing Network in a Dynamic Environment with a Changing Failure Rate ......................555
    Masahiro Tokumitsu, Yoshiteru Ishida

101. Information Sharing Between CSIRT and IDS ...................................................................................561
    Zair Abdelouahab, Fernando A. Pestana Júnior

102. Cellular Automata Used for Congestion Control in Wireless LANs ..................................................566
    Zornitza Genova Prodanoff

103. Performance Model of a Campus Wireless LAN ................................................................................571
    Seungnam Kang et al.

Author Index ...............................................................................................................................................577

Subject Index .............................................................................................................................................581
Preface

This book includes the proceedings of the 2007 International Conference on Telecommunications and Networking (TeNe) and the 2007 International Conference on Industrial Electronics, Technology & Automation (IETA).

TeNe 07 and IETA 07 are part of the International Joint Conferences on Computer, Information, and Systems Sciences, and Engineering (CISSE 07). The proceedings are a set of rigorously reviewed world-class manuscripts presenting the state of international practice in Innovative Algorithms and Techniques in Automation, Industrial Electronics and Telecommunications.

TeNe 07 and IETA 07 are high-caliber research conferences that were conducted online. CISSE 07 received 750 paper submissions and the final program included 406 accepted papers from more than 80 countries, representing the six continents. Each paper received at least two reviews, and authors were required to address review comments prior to presentation and publication.

Conducting TeNe 07 and IETA 07 online presented a number of unique advantages, as follows:

- All communications between the authors, reviewers, and conference organizing committee were done online, which permitted a short six week period from the paper submission deadline to the beginning of the conference.
- PowerPoint presentations, final paper manuscripts were available to registrants for three weeks prior to the start of the conference.
- The conference platform allowed live presentations by several presenters from different locations, with the audio and PowerPoint transmitted to attendees throughout the internet, even on dial up connections. Attendees were able to ask both audio and written questions in a chat room format, and presenters could mark up their slides as they deem fit.
- The live audio presentations were also recorded and distributed to participants along with the power points presentations and paper manuscripts within the conference DVD.

The conference organizers and we are confident that you will find the papers included in this volume interesting and useful. We believe that technology will continue to infuse education thus enriching the educational experience of both students and teachers.

Tarek M. Sobh, Ph.D., PE
Khaled Elleithy, Ph.D.,
Ausif Mahmood, Ph.D.
Mohammad A. Karim, Ph.D.
Bridgeport, Connecticut
June 2008
Acknowledgements

The 2007 International Conferences on Telecommunications and Networking (TeNe) and Industrial Electronics, Technology & Automation (IETA) and the resulting proceedings could not have been organized without the assistance of a large number of individuals. TeNe and IETA are part of the International Joint Conferences on Computer, Information, and Systems Sciences, and Engineering (CISSE). CISSE was founded by Professors Tarek Sobh and Khaled Elleithy in 2005, and they set up mechanisms that put it into action. Andrew Rosca wrote the software that allowed conference management, and interaction between the authors and reviewers online. Mr. Tudor Rosca managed the online conference presentation system and was instrumental in ensuring that the event met the highest professional standards. We also want to acknowledge the roles played by Sarosh Patel and Ms. Susan Kristie, our technical and administrative support team.

The technical co-sponsorship provided by the Institute of Electrical and Electronics Engineers (IEEE) and the University of Bridgeport is gratefully appreciated. We would like to express our thanks to Prof. Toshio Fukuda, Chair of the International Advisory Committee and the members of the TeNe and IETA Technical Program Committees including: Abdelshakour Abuzneid, Nirwan Ansari, Hesham El-Sayed, Hakan Ferhatosmanoglu, Ahmed Hambaba, Abdelsalam Helal, Gohsin Liu, Torleiv Maseng, Anatoly Sachenko, Paul P. Wang, Habib Youssef, Amr El Abbadi, Giua Alessandro, Essam Badreddin, John Billingsley, Angela Di Febbraro, Aydan Erkmen, Navarun Gupta, Junling (Joyce) Hu, Mohamed Kamel, Heba A. Hassan, Heikki N. Koivo, Lawrence Hmurchik, Luu Pham, Saeid Nahavandi, ElSayed Orady, Angel Pobil, Anatoly Sachenko, Sadiq M. Sait, Nariman Sepehri, Bruno Siciliano and Keya Sadeghipour.

The excellent contributions of the authors made this world-class document possible. Each paper received two to four reviews. The reviewers worked tirelessly under a tight schedule and their important work is gratefully appreciated. In particular, we want to acknowledge the contributions of the following individuals: A.B.M. Mozazammel Hossain, Aneesh Chand, Cao Yali, Dioubate Mamady, Eman Abdelfattah, Gayan Hettiarachchi, Grofu Florin, Hatim M tahir, Jing Zhang, K.v.d Kiran Krishnamurthy Ningappa, Kshitij Gupta, Laura Muñoz, Luis Madera, Martin Braae, Muhammad Irfan, Peter Nabende, Pramod Kumar Sharma, Praveen Kumar Kolli, Qiuyun Fu, Radu-Daniel Tomoiaga, Sarhan Musa, Sarosh H. Patel, Shafqat Hameed, Show-Shiow Tzeng, Taner Arsan, Thomas Mundt, Wang Haoping, Yenumula Reddy, and Zornitza Prodanoff

Tarek Sobh, Ph.D., P.E.
Khaled Elleithy, Ph.D.
Ausif Mahmood, Ph.D.
Mohammad A. Karim, Ph.D.

Bridgeport, Connecticut
June 2008
Kernel Locally Linear Embedding Algorithm for Quality Control

Thravouls Tsagarouilis and A. Ben Hamza
Concordia Institute for Information Systems Engineering
Concordia University, Montreal, QC, Canada
{t_tsagar, hamza}@encs.concordia.ca

Abstract- In this paper, we introduce a new multivariate statistical process control chart for outliers detection using kernel local linear embedding algorithm. The proposed control chart is effective in the detection of outliers, and its control limits are derived from the eigen-analysis of the kernel matrix in the Hilbert feature space. Our experimental results show the much improved performance of the proposed control chart in comparison with existing multivariate monitoring and controlling charts.

I. INTRODUCTION

Traditional process monitoring consists of measuring and controlling several process variables at the same time [1]. It is increasing difficult to determine the root cause of defects if multiple process variables exhibit outliers or process deviations at the same moment in time. Multivariate quality control methods overcome this disadvantage by monitoring the interactions of several process variables simultaneously and determining hidden factors using dimensionality reduction [2]. The use of multivariate statistical process control is also facilitated by the proliferation of sensor data that is typically complex, high-dimensional and generally correlated. Complex processes can be monitored the stability evaluated, using multivariate statistical process control techniques.

There are typically two phases in establishing multivariate control charts. The data collected in phase I are used to establish the control limits for phase II.

The Phase I upper control limit (UCL) and lower control limit (LCL) of the \( T^2 \) control chart are given by (4) and (5).

\[ \text{UCL} = \frac{1}{n-1} \sum_{i=1}^{n} (x_i - \bar{x})^2 (x_i - \bar{x}) \]

\[ \text{LCL} = \frac{1}{n-1} \sum_{i=1}^{n} (x_i - \bar{x})^2 (x_i - \bar{x}) \]

The remainder of the paper is organized as follows. Section II briefly reviews some existing multivariate quality control charts. In Section III, we propose a kernel LLE control chart. In Section IV, we demonstrate through experimental results that the performance of the proposed multivariate control chart has greatly been improved in comparison with existing monitoring and controlling charts. Finally, we conclude in Section V.

II. RELATED WORK

In this section, we briefly review some multivariate control charts that are closely related to our proposed approach.

A. Hotelling’s \( T^2 \)-squared statistic

Let \( X = [x_1, x_2, \ldots, x_n] \) be an \( n \times p \) data matrix of \( n \) vectors \( x_i \in \mathbb{R}^p \), where each observation \( x_i = (x_{i1}, \ldots, x_{ip}) \) is a row vector with \( p \) variables.

The Phase I of the \( T^2 \) control chart consists of establishing an outlier free reference sample [2]. Hotelling’s \( T^2 \) statistic, also referred to as Mahalanobis distance, is defined by (1).

\[ T_i^2 = (x_i - \bar{x})S^{-1}(x_i - \bar{x}) \]

Equations (2) and (3) are the sample mean and covariance matrix respectively.

\[ \bar{x} = \frac{1}{n} \sum_{i=1}^{n} x_i \] and,

\[ S = \frac{1}{n-1} \sum_{i=1}^{n} (x_i - \bar{x})^T (x_i - \bar{x}) \]

© Springer Science+Business Media B.V. 2008
In phase II, any outliers identified during phase I are removed and the remaining observations are used to recalculate the $T^2$ statistic. In other words, the Phase II $T^2$ statistic is given by (6),

$$T_i^2 = (\tilde{x}_i - \bar{x})S^{-1}(\tilde{x}_i - \bar{x})^T$$

where $\tilde{X} = [\tilde{x}_1, \tilde{x}_2, \ldots, \tilde{x}_p]^T$ is the new observed data matrix, also referred to as the historical data. Again, any historical data that is plotted outside the control limits and had an assignable cause determined are discarded. Phase II verifies if the process is generating and maintaining values that are considered in control. The control limits for phase II are defined in (7) and (8).

$$UCL = \frac{p(n+1)}{n(n-p)} F_{p,n-p} \quad (7)$$

$$LCL = \frac{p(n+1)}{n(n-p)} F_{p,n-p} - 3 \quad (8)$$

Unlike the univariate control charts, the $T^2$ statistic does not represent the original variables and therefore when an out of control situation occurs we can not determine if it was due to an excess variation of a particular variable or due to a change in the covariance/correlation matrix.

To circumvent these problems, the principal component chart may be used. This control chart can detect changes in the covariance/correlation structure and it may indicate the specific domain that created this excess variation [2]. It also has the advantage of reducing the number of dimensions that need to be analyzed [4].

### B. Principal Component Analysis

Principal component analysis (PCA) is a method for transforming the observations in a dataset into new observations which are uncorrelated with each other and account for decreasing proportions of the total variance of the original variables. Each new observation is a linear combination of the original observations.

Standardizing the data is often preferable when the variables are in different units or when the variance of the different columns of the data is substantial. The standardized data matrix is given by (9), where $I = (1, \ldots, 1)^T$ is a $n \times 1$ vector of all 1’s, and $D = \text{diag}(S)$ is the diagonal of the covariance matrix.

$$Z = (X - 11^T)D^{1/2}$$

It is worth pointing out the covariance matrix $R$ of the standardized data $Z$ is exactly the correlation matrix of the original data, and it is given by (10).

$$R = D^{-1/2}SD^{-1/2}$$

PCA is then performed by applying eigen-decomposition to the matrix $R$, that is $R = AA^T$ where $A = (a_1, \ldots, a_p)$ is a $p \times p$ matrix of eigenvectors (also called principal components) and $\Lambda = \text{diag}(\lambda_1, \ldots, \lambda_p)$ is a diagonal matrix of eigenvalues. These eigenvalues are equal to the variance explained by each of the principal components, in decreasing order of importance. The principal component score matrix is an $n \times p$ data matrix $Y$ given by (10), which is the data mapped into the new coordinate system defined by the principal components.

$$Y = ZA = (y_1, \ldots, y_p)^T$$

Moreover, the covariance of $Y$ is defined in (11).

$$\text{cov}(Y) = \frac{1}{n-1}Y^TY = \frac{1}{n-1}A^TZA = \Lambda$$

Hence, besides retaining the maximum amount of variance in the projected data, PCA also has the following property: the projected data $y_i$ are uncorrelated with variance equal to $\lambda_k$, for $k=1, \ldots, p$.

Assuming we want 99.7% confidence intervals, the upper control limit (UCL), the center line (CL) and the lower control limit (LCL) are given by (12).

$$UCL = +3\sqrt{\lambda_k}$$

$$CL = 0$$

$$LCL = -3\sqrt{\lambda_k}$$

The main drawback of principal component analysis is its sensitivity to outliers [9, 2]. In the next section, we propose a robust multivariate control chart to overcome the problems mentioned above.

### III. PROPOSED METHOD

LLE algorithm aims at finding an embedding that preserves the local geometry in the neighborhood of each data point. First, we build a sparse matrix of local predictive weights $W_{ij}$, such that $\Sigma W_{ij} = 1$, $W_{ij} = 0$ if $x_j$ is not a k-nearest neighbor of $x_i$ and then $\Sigma W_{ij}(x_i - x_j)^2$ is minimized to create the matrix $M = (I-W)^T(I-W)$. Then we define the kernel matrix $K = \Lambda_{max} I - M$, where $\Lambda_{max}$ is the maximum eigenvalue of $M$.

Suppose we have an input data set $X = \{x_i : i = 1, \ldots, n\}$ where each observation $x_i$ is a $p$-dimensional vector. Kernel LLE algorithm [10, 11] consists of two main steps: the first step is to linearize the distribution of the input data by using a non-linear mapping $\Phi$ from the input space $\mathbb{R}^p$ to a higher-dimensional (possibly infinite-dimensional) feature space $\mathcal{F}$. The mapping $\Phi$ is defined implicitly, by specifying the form of the dot product in the feature space. In other words, given any pair of mapped data points, the dot product is defined in terms of a kernel function (13).

$$K(x_i, x_j) = \Phi(x_i) \cdot \Phi(x_j)$$

In the second step, eigen-analysis is applied to the mapped data set $\Phi = \{\Phi_i : i = 1, \ldots, n\}$ in the feature space, where $\Phi_i = \Phi(x_i)$. The second step of kernel LLE is to apply eigen-analysis in the feature space by performing an eigen-decomposition on the covariance matrix of the mapped data which is given by (14), where (15) is the centered mapped data.

$$C = \frac{1}{n-1} \sum_{i=1}^n \Phi(x_i)\Phi(x_i)^T$$

$$\Phi(x_i) = \Phi(x_i) - (1/n) \sum_{i=1}^n \Phi(x_i)$$
The eigenvectors of $C$ are given by (16).
\[
\nu = \frac{1}{\mu} C \nu = \sum_{i=1}^{n} (\Phi(x_i)\cdot\Phi(x_j)) \cdot \nu = \sum_{i=1}^{n} a_i \Phi(x_j) (\mu(n-1))^{-1/2} \cdot \nu
\]
where
\[
a_i = \sum_{j=1}^{n} (\Phi(x_i)^T \nu) / (\mu(n-1))
\]
In other words, an eigenvector of $C$ is a linear combination of $\{\Phi(x_i)\}$. Taking the dot product of $\Phi(x_i)$ with $\nu$ yields (18).
\[
\Phi(x_i) \cdot \nu = \sum_{j=1}^{n} a_i \Phi(x_j) \cdot \Phi(x_i) = \sum_{j=1}^{n} a_i \tilde{K}_{ij}
\]
which implies (19).
\[
\mu(n-1)a = \sum_{j=1}^{n} a_i \tilde{K}_{ij}
\]
Hence,
\[
\tilde{K}a = \tilde{\mu}a
\]
where $a = (a_1, \ldots, a_n)$ and $\tilde{\mu} = \mu(n-1)$. That is, $a$ is an eigenvector of $\tilde{K}$. If the eigenvectors of $C$ are orthonormal (i.e. $\nu^T \nu = 1$) then (21) and hence (22), hold true.
\[
1 = \nu^T \nu = \sum_{i,j=1}^{n} a_i a_j \Phi(x_i) \cdot \Phi(x_j) = \sum_{i,j=1}^{n} a_i a_j \tilde{K}_{ij}
\]
\[
\|a\| = 1 / \mu(n-1)
\]
The main algorithmic step of our proposed kernel LLE chart as shown in Table I. The kernel LLE algorithm is based on the concepts of LLE and kernel PCA.

### Table I

**Algorithmic Steps of the Proposed Approach**

1) Construct a sparse matrix of local predictive weights $W_{ij}$, such that $\sum_{j} W_{ij} = 1$, $W_{ij} = 0$ if $x_j$ is not a $k$-nearest neighbor of $x_i$ and $\sum_{j} (W_{ij} - x_i - x_j)^2$ is minimized.

2) Construct the LLE matrix, $M = (I - W)^T (I - W)$.

3) Construct the kernel matrix, $K = \lambda_{\text{max}} I - M$.

4) $K = (K_{y})_j$ of the mapped data:
\[
K_{y} = K(x_i, x_j) = \Phi(x_i) \cdot \Phi(x_j)
\]

5) Construct the kernel matrix $\tilde{K} = H K H$ of the centered mapped data, where $H = I - J/n$ the centering matrix is defined in terms of the identity matrix $I$ and the matrix of all ones $J$.

6) Find the largest $p$ eigenvectors $a_i (r = 1, \ldots, p)$ of $\tilde{K}$ and their corresponding eigenvalues $\tilde{\mu}_i$.

7) Given a test point $x$ with image $\Phi(x)$, compute the projections onto eigenvectors $\nu_i$ given by the equation
\[
\nu_i \cdot \Phi(x) = \frac{1}{\sqrt{(n-1)}} \sum_{j=1}^{n} a_i \Phi(x_j) \cdot \Phi(x_j)
\]

Assuming we want $\pm 3 \tilde{\mu}_i$ confidence intervals, the upper control limit (UCL), the center line (CL), and the lower control limit (LCL) of the kernel LLE chart are defined in (23) to (25).

\[
UCL = +3 \sqrt{\tilde{\mu}_i}
\]
\[
CL = 0
\]
\[
LCL = -3 \sqrt{\tilde{\mu}_i}
\]

### IV. Experimental Results

We conducted experiments on three different data sets with known outliers. In all the experiments, the number of nearest neighbors was set to one less than the rank of the input matrix and the dimension of the output matrix was set to the number of input vectors.

#### A. Experiment #1: Woodmod Dataset

We tested the performance of our proposed technique on a data set $X=[x_1, x_2, \ldots, x_{20}]$ (called woodmod data [8]) which contains 20 observations as shown in Table II.

Each observation $x_i = [x_{i1}, x_{i2}, x_{i3}, x_{i4}, x_{i5}]$ has 5 variables which correspond respectively to:
- No. of fibers per square millimeter in Springwood
- No. of fibers per square millimeter in Summerwood
- Fraction of Springwood
- Fraction of light absorption by Springwood
- Fraction of light absorption by Summerwood

<table>
<thead>
<tr>
<th>TABLE II</th>
<th>WOODMOD DATASET</th>
</tr>
</thead>
<tbody>
<tr>
<td>$x_{i1}$</td>
<td>0.5730 0.1059 0.4650 0.5380 0.8410</td>
</tr>
<tr>
<td>$x_{i2}$</td>
<td>0.6510 0.1356 0.5270 0.5450 0.8870</td>
</tr>
<tr>
<td>$x_{i3}$</td>
<td>0.6060 0.1273 0.4940 0.5210 0.9200</td>
</tr>
<tr>
<td>$x_{i4}$</td>
<td>0.4370 0.1591 0.4460 0.4230 0.9920</td>
</tr>
<tr>
<td>$x_{i5}$</td>
<td>0.5470 0.1135 0.5310 0.5190 0.9150</td>
</tr>
<tr>
<td>$x_{i6}$</td>
<td>0.4440 0.1628 0.4290 0.4110 0.9840</td>
</tr>
<tr>
<td>$x_{i7}$</td>
<td>0.4890 0.1231 0.5620 0.4550 0.8240</td>
</tr>
<tr>
<td>$x_{i8}$</td>
<td>0.4140 0.1673 0.4180 0.4300 0.9780</td>
</tr>
<tr>
<td>$x_{i9}$</td>
<td>0.5360 0.1182 0.5920 0.4640 0.8540</td>
</tr>
<tr>
<td>$x_{i10}$</td>
<td>0.6850 0.1564 0.6310 0.5640 0.9140</td>
</tr>
<tr>
<td>$x_{i11}$</td>
<td>0.6640 0.1588 0.5060 0.4810 0.8670</td>
</tr>
<tr>
<td>$x_{i12}$</td>
<td>0.7030 0.1335 0.5190 0.4840 0.8120</td>
</tr>
<tr>
<td>$x_{i13}$</td>
<td>0.6530 0.1395 0.6250 0.5190 0.8920</td>
</tr>
<tr>
<td>$x_{i14}$</td>
<td>0.5860 0.1114 0.5050 0.5650 0.8890</td>
</tr>
<tr>
<td>$x_{i15}$</td>
<td>0.5340 0.1143 0.5210 0.5700 0.8890</td>
</tr>
<tr>
<td>$x_{i16}$</td>
<td>0.5230 0.1320 0.5050 0.6120 0.9190</td>
</tr>
<tr>
<td>$x_{i17}$</td>
<td>0.5800 0.1249 0.5460 0.6080 0.9540</td>
</tr>
<tr>
<td>$x_{i18}$</td>
<td>0.4480 0.1028 0.5220 0.5340 0.9180</td>
</tr>
<tr>
<td>$x_{i19}$</td>
<td>0.4170 0.1687 0.4050 0.4150 0.9840</td>
</tr>
<tr>
<td>$x_{i20}$</td>
<td>0.5280 0.1564 0.6310 0.5640 0.9090</td>
</tr>
</tbody>
</table>

The woodmod data variables are highly correlated as shown in Fig. 1, and hence multidimensional quality control charts should be applied.
Fig. 2 shows that the $T^2$ control chart is unable to detect outliers. Also, the principal component control chart is unable to detect outliers as depicted in Fig. 3. We can clearly see in Fig. 3 that the observations 4, 6, 8, and 19 have higher variations than the rest of the observations although they still lie within the upper and lower control limits.

The kernel LLE chart is able to detect the observations 2, 4, 6, 8, 10, 11, 12, 13, and 19 as outliers as shown in Fig. 4.

B. Experiment #2: Stackloss Dataset

Our second analysis was performed on a dataset called Stackloss shown in Table III. This dataset describes the plant oxidation of ammonia to nitric acid, and contains 21 observations, where each observation has 4 variables: rate, temperature, acid concentration, and stackloss.

<table>
<thead>
<tr>
<th>Observation</th>
<th>$x_1$</th>
<th>$x_2$</th>
<th>$x_3$</th>
<th>$x_4$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>80.0</td>
<td>27.0</td>
<td>89.0</td>
<td>42.0</td>
</tr>
<tr>
<td>2</td>
<td>80.0</td>
<td>27.0</td>
<td>88.0</td>
<td>37.0</td>
</tr>
<tr>
<td>3</td>
<td>75.0</td>
<td>25.0</td>
<td>90.0</td>
<td>37.0</td>
</tr>
<tr>
<td>4</td>
<td>62.0</td>
<td>24.0</td>
<td>87.0</td>
<td>28.0</td>
</tr>
<tr>
<td>5</td>
<td>62.0</td>
<td>22.0</td>
<td>87.0</td>
<td>18.0</td>
</tr>
<tr>
<td>6</td>
<td>62.0</td>
<td>23.0</td>
<td>87.0</td>
<td>18.0</td>
</tr>
<tr>
<td>7</td>
<td>62.0</td>
<td>24.0</td>
<td>93.0</td>
<td>19.0</td>
</tr>
<tr>
<td>8</td>
<td>62.0</td>
<td>24.0</td>
<td>93.0</td>
<td>20.0</td>
</tr>
<tr>
<td>9</td>
<td>58.0</td>
<td>23.0</td>
<td>87.0</td>
<td>15.0</td>
</tr>
<tr>
<td>10</td>
<td>58.0</td>
<td>18.0</td>
<td>80.0</td>
<td>14.0</td>
</tr>
<tr>
<td>11</td>
<td>58.0</td>
<td>18.0</td>
<td>89.0</td>
<td>14.0</td>
</tr>
<tr>
<td>12</td>
<td>58.0</td>
<td>17.0</td>
<td>88.0</td>
<td>13.0</td>
</tr>
<tr>
<td>13</td>
<td>58.0</td>
<td>18.0</td>
<td>82.0</td>
<td>11.0</td>
</tr>
<tr>
<td>14</td>
<td>58.0</td>
<td>19.0</td>
<td>93.0</td>
<td>12.0</td>
</tr>
<tr>
<td>15</td>
<td>50.0</td>
<td>18.0</td>
<td>89.0</td>
<td>8.0</td>
</tr>
<tr>
<td>16</td>
<td>50.0</td>
<td>18.0</td>
<td>86.0</td>
<td>7.0</td>
</tr>
<tr>
<td>17</td>
<td>50.0</td>
<td>19.0</td>
<td>72.0</td>
<td>8.0</td>
</tr>
<tr>
<td>18</td>
<td>50.0</td>
<td>19.0</td>
<td>79.0</td>
<td>8.0</td>
</tr>
<tr>
<td>19</td>
<td>50.0</td>
<td>20.0</td>
<td>80.0</td>
<td>9.0</td>
</tr>
<tr>
<td>20</td>
<td>56.0</td>
<td>20.0</td>
<td>82.0</td>
<td>15.0</td>
</tr>
<tr>
<td>21</td>
<td>70.0</td>
<td>20.0</td>
<td>91.0</td>
<td>15.0</td>
</tr>
</tbody>
</table>

The scatter plot shown in Fig. 5 confirms the existence of a high correlation between the variables. The $T^2$ control chart displayed in Fig. 6 was able to identify the last observation $m=21$ as an outlier. The principal component chart, however, did not detect any outliers as shown in Fig. 7.
On the other hand, the kernel LLE chart (see Fig. 8) was able to identify observations 1, 2, 3, 15, 16, 17, 18, and 19 as outliers.

C. Experiment #3: Phosphorus Content Data

Our third analysis was performed on a dataset (Table IV) describing the organic and inorganic phosphorus content of the soil in comparison with the corn grown. Eighteen observations were selected where each observation has three variables: inorganic phosphorus, organic phosphorus, and plant phosphorus.

<table>
<thead>
<tr>
<th>$X_{ij}$</th>
<th>$X_{i2}$</th>
<th>$X_{i3}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.40</td>
<td>53.00</td>
<td>64.00</td>
</tr>
<tr>
<td>0.40</td>
<td>23.00</td>
<td>60.00</td>
</tr>
<tr>
<td>3.10</td>
<td>19.00</td>
<td>71.00</td>
</tr>
<tr>
<td>0.60</td>
<td>34.00</td>
<td>61.00</td>
</tr>
<tr>
<td>4.70</td>
<td>24.00</td>
<td>54.00</td>
</tr>
<tr>
<td>1.70</td>
<td>65.00</td>
<td>77.00</td>
</tr>
<tr>
<td>9.40</td>
<td>44.00</td>
<td>81.00</td>
</tr>
<tr>
<td>10.10</td>
<td>31.00</td>
<td>93.00</td>
</tr>
<tr>
<td>11.60</td>
<td>29.00</td>
<td>93.00</td>
</tr>
<tr>
<td>12.60</td>
<td>58.00</td>
<td>51.00</td>
</tr>
<tr>
<td>10.90</td>
<td>37.00</td>
<td>76.00</td>
</tr>
<tr>
<td>23.10</td>
<td>46.00</td>
<td>96.00</td>
</tr>
<tr>
<td>23.10</td>
<td>50.00</td>
<td>77.00</td>
</tr>
<tr>
<td>21.60</td>
<td>44.00</td>
<td>93.00</td>
</tr>
<tr>
<td>23.10</td>
<td>56.00</td>
<td>95.00</td>
</tr>
<tr>
<td>1.90</td>
<td>36.00</td>
<td>54.00</td>
</tr>
<tr>
<td>26.80</td>
<td>58.00</td>
<td>168.00</td>
</tr>
<tr>
<td>29.90</td>
<td>51.00</td>
<td>99.00</td>
</tr>
</tbody>
</table>

The scatter plot of the data set is displayed in Fig. 9. As shown in Fig. 10, the $T^2$ control chart was able to identify the observation 17 as an outlier, whereas principal component chart did not identify any outliers as illustrated in Fig. 11. Kernel LLE chart was, however, able to detect the observations 2, 3, 4, 5, 12, 15, 16, 17, and 18 as outliers as shown in Fig. 12.
CONCLUSIONS

In this paper, we proposed a robust multivariate control chart for outlier detection using kernel locally linear embedding algorithm. The core idea behind our proposed technique is to project the data into a Hilbert space in order to extract the eigenvalues and eigenvectors of a kernel matrix. The experimental results clearly show a much improved performance of the proposed approach in comparison with the current multivariate control charts.

REFERENCES

A New Method for Synchronization and Control of the Chen Chaotic System

Afshin Izadian, Boyd Edwards, and Parviz Famouri, Senior Member, IEEE

Abstract—chaotic behavior of dynamical systems can be utilized in many applications such as secure communication systems, heart arrhythmias, and chemical reactors. In this regard, they are required to be regulated and synchronized with desired references and obtain specific functionality. This paper introduces the application of an input-output controller to synchronize the Chen chaotic system with desired references. Adaptive techniques are applied for gain adaptation and the system is controlled to track arbitrary trajectories. The performance of the control is compared with other types of controllers.

I. INTRODUCTION

Dynamical systems under specific conditions show chaotic behavior which often possess a wideband power spectrum and random characteristics in time domain [1]. Chaotic systems are very sensitive to the initial conditions such that a very small perturbation results in a large variation in their behavior.

Chaotic behavior of dynamical systems can be utilized in many applications if they are required to follow a desired pattern such as secure communication systems where a random modulation is required and must be synchronized at both ends of the communication transmission line [2]. Control and synchronizing techniques are required to provide a fast and accurate trajectory controls for these types of applications. Chaotic system mainly possess high order (>2) nonlinear dynamics which can better be controlled by nonlinear control approaches. The performance of the control depends on the power of the controller and its ability to follow the sudden variations. A suitable controller ideally contains a simple structure and requires minimum information about the system under control. It generates minimum control command and controls the plant in a short time. It should be robust against the plants parameter variations. Several techniques are recommended for control of chaotic systems such as stochastic control, Lyapunov methods, robust feedback control, and feedback linearization, feedback control of bifurcation, variable structure control techniques [3] and passive control techniques [4]. These techniques mainly depend on the system parameters and state variables which require accurate modeling and state observers.

This paper utilizes a new input-output controller with a new adaptation technique and a model to synchronize the plant’s output (chaotic system) with that of the model or an arbitrary reference. Chen chaotic system with almost the same structure as Lorenz attractor (dual of the Lorenz [5]) is studied and used for synchronization technique. The controller is applied to control the output of the reference with that of the plant excited at different initial conditions.

The paper is organized as follows: the next section is an introduction to Chen chaotic system, and in section 3 the controller structure is illustrated. Simulation results and tracking performance are discussed in section 4.

II. CHEN CHAOTIC SYSTEM

The dynamics of the Chen chaotic system is described as follows [5]:

\[
\begin{align*}
\dot{x} &= a(y-x) \\
\dot{y} &= (c-a)x - xy + cy \\
\dot{z} &= xy - bz
\end{align*}
\]

(1)

Chaotic behavior occurs when \(a=35\), \(b=3\), and \(c=28\). The structure of the Chen chaotic system is almost similar to that of the Lorenz attractor where the chaotic behavior occurs at \(a=28\), \(b=8/3\) and \(c=10\).

The Chen dynamical system shows three sets of fixed points which result in saddle node and unstable spirals described as follows: The fixed point at the origin results in the eigenvalues \((-0.8359), (23.8359), \) and \((-3),\) implying a saddle node. Two other fixed points share the eigenvalues at \((-18.4280),\) and \((4.2140 \pm 14.8846i)\) since the real parts of these eigenvalues are positive; the linearization theory predicts these fixed points to be unstable spirals. The system’s chaotic behavior at the unit initial condition is shown in Figure 1. For control purposes, the original nonlinear system is being controlled by applying a control command \(u(t)\) to the z-axis of the system as follows [4]:

\[
\begin{align*}
\dot{x} &= a(y-x) \\
\dot{y} &= (c-a)x - xy + cy \\
\dot{z} &= xy - bz + u
\end{align*}
\]

(2)

The system’s chaotic behavior is shown in Figures 2 and 3.
Definition 1: The Chen chaotic system is minimum phase if it has relative degrees \{1, 1, 1\}.

Definition 2: Two chaotic systems are synchronized if the error dynamic system between their outputs is asymptotically stable [2].

In this paper, we consider one of the chaotic systems as model reference and the other as a plant to be controlled. The control objective is to synchronize these two systems while they start at different initial conditions. The other control objective is to be able to synchronize any state parameters of the chaotic system with an arbitrary reference.

III. SYNCHRONIZATION TECHNIQUE

The control command to the z-axis of the Chen chaotic system can be defined as follows: [6]

\[ u = k_p y_p + k_e (y_p - y_m) + k_r r \]  \hspace{1cm} (7)

where \( k_r, k_e, k_p \) are the controller coefficients and are being adjusted according to the gain adaptation techniques, and \( y_m, y_p \) which are the model reference and plant’s output signals. Any of the system state variables can be chosen as an output. \( r \) is defined as the model reference input. In a perfect tracking condition, the coefficients of \( k_r, k_e, k_p \) are chosen such that the zero error conditions hold. Estimations of these coefficients are introduced as \( \hat{k}_r, \hat{k}_e, \hat{k}_p \) and result in the equivalent control command as follows:

\[ u_{eq} = \hat{k}_p y_p + \hat{k}_e e + \hat{k}_r r \]  \hspace{1cm} (8)

where control gain coefficients are updated according to the following adaptation techniques:

\[ \dot{\hat{k}}_r = -P_0 \text{sgn}(s) r \]  \hspace{1cm} (16)

\[ \dot{\hat{k}}_p = -P_0 \text{sgn}(s) y_p \]  \hspace{1cm} (17)

\[ \dot{\hat{k}}_e = -P_0 \text{sgn}(s) e \]  \hspace{1cm} (18)

with \( P_0 > 0 \) is a positive value and \( s \) is defined as the sliding surface \( s = Ge = 0 \) in which \( G \) is the switching gain matrix and \( e = y_p - y_m \) is the tracking error.

Seeking zero error conditions the switching matrix can be considered as identity value. The proof of stability is introduced in [8].

---

Fig. 1. Chaotic behavior of the Chen system in x, y, and z-axes.

Fig. 2. 2D Chaotic behavior of the Chen system respect to different axes.

Fig. 3. 3-D chaotic behavior of Chen system.
IV. Simulation Results

As mentioned earlier, the chaotic systems were excited initially at different values. First, the systems were allowed to oscillate individually for 0.5 seconds. The output of the chosen axes oscillated differently as shown in Figure 4. Then (at $t=0.5$) the control command was applied to the plant to force its output track the desired reference signal. The synchronization and tracking profile of the x-axis of the plant with the y-axis of the model is shown in Figure 4. The synchronization is completed in less than one second. Figure 5 shows the tracking error and the adaptation process. At higher adaptation gains, faster adaptation occurs which requires higher control efforts.

For an arbitrary reference signal (not chaotic), the adaptation time is less than 0.2 seconds. Figure 6 shows the tracking profile for an arbitrary reference signal. The control command was applied at time $0.5$ second, and before that systems were oscillated differently.

![Synchronization Profile](image1)

Fig. 4. The synchronization is completed in less than a 0.8 sec. The synchronization time is at $t=0.5$ sec. The controller is turned on and applied to the system to synchronize the $Y_d$ and $X_r$.

![Tracking Error](image2)

Fig. 5. The synchronization error and its stability. As time increases the synchronization, error reaches zero.

![Synchronization Profile](image3)

Fig. 6. Synchronization with an arbitrary reference. The controller is switched on at time $t=0.5$ sec and is forced to follow an arbitrary sine wave. The x-axis output of the response system tracks the variations of the reference and is synchronized with the reference signal in tile less than 0.2 seconds.
Xiaoxin Liao et. al, have reported an error dynamic analysis approach in which the same state variables of the Chen chaotic system have been synchronized [5]. In the new synchronization approach, the synchronization time for x-state variable is much shorter than that of reported in [5]. Moreover, the synchronization of different axes was applicable. Synchronization of Chen chaotic system with an arbitrary reference shows the flexibility of the controller.

CONCLUSION

A new controller-synchronizer was designed for the Chen chaotic system. The controller made use of a new adaptation law for its parameter adjustment. The controller was applied to synchronize the Chen chaotic system with the output of another identical chaotic system and with an arbitrary trajectory. A comparison with other controllers showed a faster and more accurate controller with more degrees of freedom in synchronization.

REFERENCES

The Intra Prediction in H.264
Ahmad Khalil Khan and Habibullah Jamal
Department of Electrical Engineering,
University of Engineering and Technology,Taxila
profkhalil@uettaxila.edu.pk , drhjamal@uettaxila.edu.pk

Abstract: A multidirectional spatial prediction method to reduce spatial redundancy by using
neighbouring samples as a prediction for the samples in a block of data to be encoded is
already included in the H.264/AVC. The spatial prediction may be performed on sample wise
DPCM instead of the block-based manner as used in the current H.264/AVC standard. The
block structure is retained for the residual difference entropy coding process. There are two
approaches of spatial prediction i.e. sample prediction and block prediction. The Second
approach is more efficient. It is being introduced into the H.264/AVC standard as an
enhancement. This paper is a brief survey of what is important in intra prediction and with
some experimental work. The work involves running of the code of H.264.

1. INTRODUCTION

Video coding standard H.264/AVC was developed by Joint Video Team (JVT). It
outperforms the previous compression standards in many respects due to the added new features.
Any reference may be consulted in this respect but we will restrict our discussion to the intra
prediction.
The formation of a prediction block P based on previously encoded and reconstructed blocks and
subtracted from the current block prior encoding is called intra mode prediction. P is formed for
each 4x4 block or for a 16x16 macroblock. There are nine prediction modes available for 4x4 luma
block, four modes for a 16x16 luma block and four modes for the chroma blocks. The
prediction mode for each block that minimizes the difference between P and the current block is
selected[1].

The difference of intra block output and the current block is the residual and it is going to be
transformed and then quantized. This signal is transmitted with some signal processing and
demodulated and some previously reconstructed picture is added to it to reconstruct a picture.
Similarly when one part is going to the transmitter the other part is inverse quantized and
then transformed to get the reference picture which is used to predict macroblock. It takes
more than 8% of the computational time [2].

The types of intra coding are supported based on slice-coding types like Intra_4x4 or Intra_16x16
together with chroma prediction. The Intra_4x4 mode means each 4x4 luma block which is used
for coding of parts of a picture. The Intra_16x16 mode means 16x16 luma block which is used for
coding smooth areas of a picture. A separate chroma prediction of 8x8 is also used.

In H.264/AVC intra prediction is conducted in the spatial domain by referring to neighbouring
samples of previously-coded blocks which are to the left and for above the block to be predicted.
Because of this a constrained intra mode is transmitted that allows prediction only from
intra-coded neighbouring macroblocks.

For Intra_4x4 mode, each 4x4 block is predicted from spatially neighbouring samples as illustrated in Fig.1a and Fig.1b.

Fig.1a. For Intra_4x4 eight predictions directions

Fig.1b. Intra_4x4 for samples a-p of a block using samples A-Q.

© Springer Science+Business Media B.V. 2008
The 16 samples from a to p of 4x4 block are predicted using prior decoded samples in adjacent blocks labeled as AQ. There are nine prediction modes available. In DC prediction one value is used to predict the entire 4x4 block and other two out of eight modes are illustrated as shown in Fig.2.[3].

In Fig.2 a few of the nine Intra_4x4 prediction modes are shown. For the vertical prediction or mode0, the sample above the 4x4 block are copied into the block as indicated by the arrows. In the horizontal prediction (mode1) the samples to the left of the 4x4 block are entered. For DC prediction or mode2 the adjacent samples average is taken. The other modes not shown are diagonal prediction modes. They are named as diagonal-down-left (mode3), diagonal-down-right (mode4), vertical-right (mode5), horizontal-down(mode6), vertical-left (mode7) and horizontal-up(mode8) [3].

Intra_16x16 has four prediction modes. Vertical prediction (mode0), horizontal prediction (mode1), DC prediction (mode2) and plane prediction (mode3) are supported. They are specified just like the modes in Intra_4x4 prediction. Instead of four neighbours on each side, 16 neighbours on each side to a block are used. Using a similar prediction technique the chroma samples are predicted[1].

Mode decision technique may be based on rate-distortion optimization. For all possible modes rate-distortion cost is calculated and the best one having minimum rate-distortion is chosen. For the purpose high computational complexity is required. To keep the complexity low two methods are used: i) early SKIP mode decision ii) Selective intra mode decision .[4][5].

Without significant rate-distortion performance degradation the complexity of the encoder is discussed in [6]. Intra-frame prediction and I_PCM prediction is treated well in [3]. In the prediction procedure integer motion estimation (IME), fractional motion estimation (FME) and intra prediction (INTRA) are included. The computational complexity of different components may be given as : Integer Motion Estimation is 52.034%, intra prediction 0.544% and sub_pixel residue/Hadamard 37.207%.[7].

In H.264 the rate-distortion (R-D) optimization is the main complexity source.[8]. Architectures and designs for H.264/AVC intra frame coders etc are considered.[7],[9],[10],[11],[12].

A YUV picture of a video sequence is represented by three rectangular arrays of integer valued samples. One of these arrays is called the luma component and shows the brightness at each sample location. The other two arrays are typically called the chroma arrays of the same. At each sample they represent the color-difference chromaticity. For 4:4:4 all the three arrays are of the same dimension. For 4:2:0 each chroma array is half the width and half of the length of the luma array. For 4:2:2 the chroma arrays are half in width but of the same height.[13].

2. THE INTRA PREDICTION MODE SELECTION

The intra mode that meets the best Rate-distortion tradeoff can be determined. The mode is determined by minimizing the Lagrangian functional :

$$J(s,c,\text{MODE} \mid \text{QP} , \lambda_{\text{MODE}}) = \text{SAD}(s,c,\text{MODE} \mid \text{QP}) + \lambda_{\text{MODE}} \cdot \text{R}(s,c,\text{MODE} \mid \text{OP})$$

Where QP = Quantization parameter 
\(\lambda_{\text{MODE}}\) = Lagrange multiplier for mode decision

\[\text{SAD}() = \text{Sum of absolute differences between the original blocks and its reconstruction} \]
\[\text{MODE} = \text{Prediction mode[14].} \]
3. THE LOSSY AND LOSSLESS CODING

The H.264/MPEG-4 AVC video coding standard developed in 2003, was developed jointly as ITU-T Recommendation H.264 and ISO/IEC 14496-10 (MPEG-4 part 10) Advanced Video Coding (AVC) is a remarkably efficient lossy video coding standard. Its lossless encoding capabilities are also important. Pulse-code modulation (PCM) macroblock coding mode represented samples of selected macroblock losslessly. It was inefficient from a compression perspective.

The fidelity range extension (FRExt) included the design improvements for more efficient lossless encoding. Further improvements in these lossless encoding techniques have already been adopted.[13].

Block-based prediction in H.264/AVC which is intra picture prediction consisting of using selectable position-dependent linear combinations of neighbouring sample values to form a prediction block.

The goal of the prediction processing is to reduce the quantity of data needed to adequately represent the corresponding block of input picture samples. Intra prediction is used for random access, video sequence editing, still picture coding and significant changes of scene content.

Lossless compression is included in the Fidelity Range Extension (FRExt) capability. H.264/AVC adopts FRExt for high resolution video to HDTV. Several parts are added by FRExt to improve the coding efficiency and visual quality at HDTV level including 8x8 transformed newer quantization technique and 8x8 intra prediction. Intra prediction is used in intra slices and may also be used in P and B slices and further 8x8 intra prediction increases the speed of the operation.[15].

There are three basic types of intra prediction 16x16, 8x8 and 4x4 in H.264/AVC. Nine intra prediction modes for 8x8 and 4x4 intra prediction are used.

The AC energy coefficient tells the complexity of the texture. For a complex texture the size of the block for intra prediction is chosen as smaller otherwise a larger block may be chosen. For the purpose the ratio of AC/DC is used to predict the intra prediction block size.[15]

To compute DC and AC coefficient energy in pixel domain, the following equations are used [15].

\[
DC\_energy = 1/8 \times 8 \left( \sum_{m=0}^{7} \sum_{n=0}^{7} a_{mn} \right)
\]

\[
AC\_energy = \left( \sum_{m=0}^{7} \sum_{n=0}^{7} a_{mn} \right) - DC\_energy
\]

Where amn is the data in a block.

A normalized AC_DC ratio is

\[
AC\_DC\_ratio = \frac{AC\_energy}{log (DC\_energy \times 64)}
\]

It is normalized between 0-1.

QP is also used to determine the smoothness. The effect of QP to cost function without RDO is linear. The threshold can be a linear equation of QP

\[
Th = a \times Qp + b
\]

\[
a = 0.0091, b = 0.236
\]

These values are used extensively to determine the block type.[15]

4. EXPERIMENTAL WORK

JM9.5 is the standard Code for H.264. It is written in C. It may be run with the required changes in the C code. The code was prepared by the Joint Video Team (JVT) and updated continuously which makes it responsive to day by day additions.[16]. In all coding processes the first frame is always intra coded., other wise it is not possible to start and update the picture transmission with compression. A parameter named as intraperiod in the code determines the number of frames to be coded as intra. When its value is zero then only fist frame is coded as intra. When intraperiod is one then the sequence is like IPPPP... and likewise we can get other sequences. The number of bits required is increased as the contribution of the intra frames is increased. All this is in line with our perception. Consequently the compression continues to decrease. The SNRs in case of Y,U and V also continue to increase when the contribution of intra increased.
5. CONCLUSION

After a brief survey of different techniques it is obvious that in all types of compression techniques the first frame is intra coded for the reasons already mentioned. The signal to noise ratio continues to increase with intra coding. These are our common observations. Different modes used in case of intra prediction contribute towards the increase of compression.

![Effect of Inserting more Intra Frames](image)

Fig. 4. Effect of inserting more intra frames by increasing intra period (From top to bottom) a; Average SNR Y, b; Average SNR U, c; Average

6. REFERENCES


[5]. Yu-Wen Huang; Bing-Yu Hsieh; Tung-Chien Chen; Liang-Gee Chen Analysis, fast algorithm, and VLSI architecture design for H.264/AVC intra frame coder, Pages 378-401 IEEE Transaction on The circuit and system for video Technology,2004


[10]. Chen-Han Tsai; Yu-Wen Huang; Liang-Gee Chen; Algorithm and architecture optimization for full-mode encoding of H.264/AVC intra prediction Circuits and Systems, 2005. 48th Midwest Symposium on 7-10 Aug. 2005 Page(s):47 - 50 Vol. 1

[11]. Yu-Wen Huang; Tung-Chien Chen; Chen-Han Tsai; Ching-Yeh Chen; To-Wei Chen; Chi-Shi Chen; Chun-Fu Shen; Shyh-Yih Ma; Tu-Chih Wang; Bing-Yu Hsieh; Hung-Chi Fang; Liang-Gee Chen; A 1.3 TOPS H.264/AVC single-chip encoder for HDTV applications Solid-State Circuits Conference, 2005. Digest of Technical Papers. ISSCC. 2005 IEEE International 6-10 Feb. 2005 Page(s):128 – 588 Vol. 1


ABSTRACT – In this dissertation, a wireless network of sensors was implemented for the monitoring of physical variables, consisting of a software-hardware platform in keeping with the design model of virtual instruments. The communication protocols used were RS232 and ZigBee; the network is made up of various modules, each one consisting of five sensors and one Zigbee transmitter. These modules, in turn, communicate wirelessly with a ZigBee receiver module that is linked up to the RS232 port of a personal computer that administers the entire system. In developing the software, we used a object-oriented programming paradigm, Java programming language, the LINUX operating system, all of which are open source; this, together with the electronic elements used, makes for a low-cost system that can be used for industrial purposes by both small and medium-sized enterprises (SMEs) enhancing both their productivity as well as their competitiveness.


I. INTRODUCTION

Wireless networks are constantly evolving and are now gradually replacing cable network technology given their inherent flexibility and the fact that they can be easily installed. Their development and technology have been such, that little devices called sensors have been incorporated in these networks. This has led us to become acquainted with this recent technology, that is innovative and able to provide quick and reliable solutions to the problems that arise. Their capacity to monitor and manipulate physical elements or phenomena give rise to enormous possibilities for almost any scientific discipline. In particular, our investigation group has directed its applications towards environmental monitoring and precision agriculture; and in the latter case with a view to contributing to the development of Colombia, which represents significant potential in this sector.

The hardware-software platform was designed associating the sensors to virtual instruments, whose communication (data transfer) system implements the ZigBee protocol. Virtual Instrumentation (VI) is a concept that was introduced by National Instruments through its software laboratory Virtual Instrument Engineering Workbench (LabVIEW); VI allows a personal computer (PC) to be used as a measuring instrument. In this way the concept of VI has been conceived as “an instrument that is not real, that is implemented by means of a computer and whose functions are defined by the software” [2], [3], [4].

The platform thus developed can be adapted by making minor modifications to other applications such as the distributed automation [5], [6], [7], [8].

II. MATERIALS AND METHODS

A. The software

In designing and implementing the VI the object-oriented programming paradigm was used. The programming language used is Java and for the IDE (Integrated Development Environment) the NetBeans 5.5, was used both of which are sourced by Sun Microsystems All this is open source software [9].

The dynamic polymorphism, implemented through inheritance is applied to the design of the VI allowing the instruments to be extended in a transparent fashion with an efficient reuse of the code. The classes responsible for communicating are totally detached from the instrument code, which facilitates the adaptation of any new communication protocol. The VI was built in compliance with the requirements of the Java language, so that they could become JavaBean components, thereby accelerating the development of control panels through a IDE.

B. The hardware

The sensor/transmitter unit

This is responsible for obtaining data from the sensor and sending this to the receiver unit. It consists mainly of: a PIC16f877a microcontroller, a TTL to CMOS level shifter and a XBee-PRO transmitter unit.

The receiver unit

This is responsible for receiving the data sent by the sensor unit and sending it onto the PC through its serial port. It consists...
mainly of: a XBee-PRO receiver module, a TTL to CMOS level shifter and a Max232 integrated circuit. It is interesting to see the properties of the XBee-PRO chip (Fig. 1) which is the basic element used for the network’s wireless communication and implements the ZigBee protocol. It is manufactured by MaxStream and has the following fundamental specifications (Table 1).

![XBee-PRO](image)

**Table 1**

<table>
<thead>
<tr>
<th>Property</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>2.4 GHz</td>
</tr>
<tr>
<td>Power</td>
<td>60 mW (18 dBm)</td>
</tr>
<tr>
<td>Indoor</td>
<td>100 m</td>
</tr>
<tr>
<td>Outdoor</td>
<td>1.6 Km</td>
</tr>
<tr>
<td>Transmission rate</td>
<td>250 Kps</td>
</tr>
<tr>
<td>Number of channels</td>
<td>12</td>
</tr>
<tr>
<td>Size</td>
<td>2.438 cm x 3.294 cm</td>
</tr>
<tr>
<td>Network Topology</td>
<td>Peer-to-peer</td>
</tr>
<tr>
<td></td>
<td>Point-to-point</td>
</tr>
<tr>
<td></td>
<td>Point-to-multipoint</td>
</tr>
<tr>
<td>Voltage</td>
<td>2.8 - 3.4 Volts</td>
</tr>
</tbody>
</table>

The sensors

In order to test the network the following was used: 1 temperature sensor (LM335AZ from National Semiconductors), 2 brightness sensors (VT43N1 and VT400 from PerkinElmer Optoelectronics), 1 infrared (OP593 from Optek technology Inc) and 1 magnetic field detector (AU-MS-03R from AUPAX INDUSTRIAL(HK) CO., LIMITED).

### III. RESULTS

#### A. The Software

A JavaBeans was developed called GaugeCircular.java as an extension of the JComponent and that implements the Serializable interface that provides the instrument with persistence. It possesses the set and get public methods that allow for its visualization (colors) to be varied and the measurement scale to be defined (minimum value, maximum value, number of divisions and subdivisions and the measurement unit), and the setLectura (double dato) public method which receives the result of the measurement and calls the instrument to repaint. Fig. 2 contains an illustration of the graphic interface corresponding to the monitoring of a sensor unit: here five examples of this virtual instrument are found in the upper panel.

![Graphical Interface of one unit sensor](image)

**Fig. 2**: Graphical interface of one unit sensor.
The Drawing JavaBean

This JavaBean called the GraficaXY.java, is able to display in real time the graphic result of monitoring the measured variable; this was developed using the open source software package JFreeChart version jfreechart-1.0.0-rc1\[10\]. As a class, it is an extension of the JComponent and also implements the Serializable interface. It possesses the set and get public methods that allow for its appearance to be modified (colors, headings and subheadings of the graph and its axes) the setDato (double x, double y) public method in order to receive the data, the borrarDatos() public method to erase data together with the private internal auto-scaling methods Fig. 2 illustrates five examples of this bean in the middle panel.

The javabean that displays data in table form

This JavaBean called Tabla.java, is responsible for displaying in real time the results of the measurement. The measurement’s number time and value. This is an extension of JPanel and implements the Serializable interface. It possesses the set and get public methods that allows for its appearance to be modified (colors, headings of the columns. It also has the setValoresTabla (double x, double y) public method to receive data and the borrarDatos() public method to erase the data. Fig. 2 illustrates five examples of this bean in the middle panel.

The class responsible for the data

Since we had in mind a network made up of stations containing sensor units each containing sensors, a data storage structure (current data) was adopted, consisting of a matrix order arrangement i × j × k , whereby i stands for the number of the station, j for the number of the sensor unit and k the number or the sensor. Please refer to Fig. 3.

The Classes responsible of communication

The communication with the PC is done through the serial port (RS232 protocol). There were implemented 3 classes for this: ComunicacionPuertoSerial, ConfiguracionRS232 and ParametrosPuertoSerial. The last two ones are in charge of the port configuration and location. The first one handles the serial communication; it implements the SerialPortEventListener, Runnable interfaces and reads the port every 100 ms (this sampling time can be changed), and obtains data from the receiver ZigBee module in ASCII strings that obey a defined protocol and envelope the information about station number, sensor unit number and measurement values of all sensors of the unit; this class is also responsible of the conversion of the information into four data: int estacion, int unidad, int sensor, double dato, and the delivery to Almacen_RAMDatos class.

The graphical interface

Fig. 4 illustrates the displayed graphical interface when the application is executed. In the menu bar are four buttons: the first one (from left to right) is to access to the serial port configuration; the second one starts the communication between the application and the receiver ZigBee module; the third one ends the communication and the fourth one allows the exit of the application.

Two panels were implemented; each one with 12 buttons for the access to the stations and its sensor units: in the figure, sensors of unit 1 and station 1 are being accessed.