

Smart Sensors, Measurement and Instrumentation

Volume 14

Series editor

Subhas Chandra Mukhopadhyay
School of Engineering and Advanced Technology (SEAT)
Massey University (Manawatu)
Palmerston North
New Zealand
E-mail: S.C.Mukhopadhyay@massey.ac.nz

More information about this series at <http://www.springer.com/series/10617>

Nagender Kumar Suryadevara
Subhas Chandra Mukhopadhyay

Smart Homes

Design, Implementation and Issues

Nagender Kumar Suryadevara
Massey University (Manawatu)
Palmerston North
New Zealand

Subhas Chandra Mukhopadhyay
Massey University (Manawatu)
Palmerston North
New Zealand

ISSN 2194-8402 ISSN 2194-8410 (electronic)
Smart Sensors, Measurement and Instrumentation
ISBN 978-3-319-13556-4 ISBN 978-3-319-13557-1 (eBook)
DOI 10.1007/978-3-319-13557-1

Library of Congress Control Number: 2014956879

Springer Cham Heidelberg New York Dordrecht London

© Springer International Publishing Switzerland 2015

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, express or implied, with respect to the material contained herein or for any errors or omissions that may have been made.

Printed on acid-free paper

Springer International Publishing AG Switzerland is part of Springer Science+Business Media
(www.springer.com)

Dedicated to

Our parents:

Mr. Sree Rama Murthy Suryadevara

Mrs. Ratna Kumari Suryadevara

Mr. D.N. Mukhopadhyay

Mrs. R.R. Mukhopadhyay

Our wives:

Mrs. Jyotsna Suryadevara

Dr. K.P. Jayasundera

Our children

Miss. Nirmala Suryadevara

Miss. Roopali Suryadevara

Miss. Sakura J. Mukhopadhyay

Master Hiroshi J. Mukhopadhyay

Preface

In this research, we have designed, developed and implemented a wireless sensor networks based smart home for safe, sound and secured living environment for any inhabitant especially elderly living alone. We have explored a methodology for the development of efficient electronic real time data processing system to recognize the behaviour of an elderly person. The ability to determine the wellness of an elderly person living alone in their own home using a robust, flexible and data driven artificially intelligent system has been investigated. A framework integrating temporal and spatial contextual information for determining the wellness of an elderly person has been modelled. A novel behaviour detection process based on the observed sensor data in performing essential daily activities has been designed and developed. The model can update the behaviour knowledge base and simultaneously execute the tasks to explore the intricacies of the generated behaviour pattern. An initial decline or change in regular daily activities can suggest changes to the health and functional abilities of the elderly person.

The developed system is used to forecast the behaviour and quantitative wellness of the elderly by monitoring the daily usages of household appliances using smart sensors. Wellness determination models are tested at various elderly houses, and the experimental results related to the identification of daily activities and wellness determination is encouraging. The wellness models are updated based on the time series analysis formulations. The integrated smart sensing system is capable of detecting human emotion and behaviour recognition based on the daily functional abilities simultaneously. The electronic data processing system can incorporate the Internet of Things framework for sensing different devices, understand and act according to the requirements of smart home environment.

Subhas Chandra Mukhopadhyay
Nagender Kumar Suryadevara

Contents

1	Introduction	1
1.1	Background	3
1.2	Major Objective of the Research.....	4
1.3	Determining Wellness of an Elderly Person	4
1.4	Scope of the Research	5
1.5	Research Direction	6
1.6	Novel Contribution of the Research.....	6
1.7	Research Significance	7
1.8	Outline of the Book.....	7
	References	8
2	Smart Home Related Research	11
2.1	Introduction.....	11
2.2	Elderly People and Independent Living	12
2.3	Smart Home Systems	15
2.4	Components of the Smart Home Systems	16
	2.4.1 Physical Components	17
	2.4.2 Communication Mechanism.....	18
	2.4.3 Information Processing	19
2.5	Comparisons of Smart Home Systems.....	19
2.6	Review of Methodologies on ADL Recognition in SHMS	28
2.7	Smart Homes Technologies Users	38
2.8	Advantages of a Smart Home Technology.....	38
2.9	Current Limitations of Smart Home Technologies	38
2.10	Impact of Smart Homes Technologies on Societies	40
2.11	Smart Systems and Internet of Things (IoT)	41
2.12	Applications of IoT	41
2.13	Chapter Summary.....	43
	References	44

3	Design and Deployment of WSN in a Home Environment and Real-Time Data Fusion	53
3.1	Introduction	53
3.2	Description of the Wireless Sensing Systems	54
3.3	Wireless Sensing Systems for Household Objects Monitoring and Control.....	56
3.3.1	Type #1 Electrical Household Objects Monitoring and Control Sensing System	56
3.3.2	Type #2 Non-electrical Objects Sensing System	65
3.3.3	Type #3 Contact Sensing System for Domestic Objects	66
3.3.4	Type #4 PIR Sensing System for Movements Monitoring.....	66
3.3.5	Type #5 Environmental Parameters Monitoring Sensing System.....	67
3.3.6	Type #6 Physiological Parameters Monitoring System.....	69
3.3.7	Human Emotion Recognition System	70
3.4	Networking Wireless Sensing Systems	71
3.4.1	Advantages of XBee Modules.....	71
3.5	Topologies of Wireless Sensing System	72
3.6	Placement of Different Sensing Systems in a Home	73
3.7	Required Number of Sensing Systems at an Elderly Person Home	75
3.8	Computer Based Data Acquisition Systems	77
3.9	Real-Time Heterogeneous Sensor Data Fusion.....	78
3.10	Software System for Sensor Data Acquisition	80
3.11	WSN Data Storage Mechanism.....	81
3.12	Query Processing Mechanism for the WSN Data Stream.....	82
3.13	IoT Framework.....	85
3.14	Results.....	86
3.14.1	Sampling Rates for Wireless Sensing Systems	88
3.14.2	Quality of Service factors of the Wireless Sensing Systems	90
3.14.3	Reliability	92
3.14.4	Throughput Measurements	93
3.14.5	Database Statistics.....	96
3.15	Troubleshooting with XBee Modules	103
3.16	Limitations of the Developed Wireless Sensing Systems	104

3.17	Sensor Data Analytics for Wellness Determination of an Elderly Person.....	104
3.18	Chapter Summary.....	107
	References	107
4	ADLs Recognition of an Elderly Person and Wellness Determination	111
4.1	Introduction.....	111
4.2	Design of ADLs Recognition System	112
4.3	ADLs Annotation	114
4.3.1	ADL Sub-Activities (Chores) Identification	115
4.3.2	Delta Smoothing for Sub-Activities Identification.....	119
4.4	Wellness Determination of an Elderly Person Based on the Usages of Household Appliances.....	120
4.4.1	Wellness Function #1	121
4.4.2	Wellness Function #2	122
4.4.3	Need for Dynamic Wellness Functions.....	122
4.4.4	Improved Wellness Function #1.....	123
4.4.5	Improved Wellness Function #2.....	124
4.4.6	Maximum Inactive and Excess Active Usage Durations (T, T _n).....	125
4.5	Results and Analysis	126
4.6	Chapter Summary.....	134
	References	135
5	Forecasting the Behaviour of an Elderly Person Using WSN Data.....	
5.1	Introduction.....	139
5.2	Time Series Modeling and Forecasting.....	140
5.3	Seasonal Decomposition	142
5.4	Deriving Trend Using Modified Double Exponential Smoothing Process.....	143
5.5	Behaviour Detection.....	143
5.6	Results and Analysis	144
5.7	Chapter Summary.....	154
	References	155
6	Sensor Activity Pattern (SAP) Matching Process and Outlier Detection.....	
6.1	Introduction.....	159
6.2	Sensor Activity Pattern (SAP) Algorithm	162
6.2.1	Notations and Definitions of the SAP Algorithm.....	162
6.3	Results and Analysis	164

6.4	Sensor Activity for ADL Pattern Discovery	169
6.5	Outlier Detection.....	171
6.6	Chapter Summary.....	172
	References	172
7	Conclusions	177