

Smart Health Systems

Emerging Trends

Sonali Vyas

Deepshikha Bhargava



Springer

Smart Health Systems

Sonali Vyas • Deepshikha Bhargava

Smart Health Systems

Emerging Trends

Sonali Vyas
Department of Computer Science
University of Petroleum and Energy Studies
Dehradun, India

Deepshikha Bhargava
Department of Computer Science
University of Petroleum and Energy Studies
Dehradun, India

ISBN 978-981-16-4200-5 ISBN 978-981-16-4201-2 (eBook)
<https://doi.org/10.1007/978-981-16-4201-2>

© Springer Nature Singapore Pte Ltd. 2021

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, expressed or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

This Springer imprint is published by the registered company Springer Nature Singapore Pte Ltd.
The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

Contents

1	Smart Health: An Introduction	1
1.1	What Is Smart Health?	2
1.2	Objectives of Smart Healthcare	3
1.3	Requirements of Smart Healthcare	3
1.4	Characteristics and Classification of Smart Healthcare	4
1.5	Components of a Smart Healthcare System	4
1.6	Key Concepts in Smart Healthcare	6
1.6.1	eHealth	6
1.6.2	Digital Health	7
1.6.3	mHealth	7
1.6.4	Smart Health IT	8
1.6.5	Smart Hospitals	8
1.7	Concluding Remarks	8
	References	9
2	Technologies for Smart Health	11
2.1	Impacts of Technologies on Smart Healthcare	11
2.2	Next-Generation Technologies for Smart Healthcare	12
2.2.1	RFID Technology	12
2.2.2	IoT Technology and 5G Networks	13
2.2.3	Big Data	14
2.2.4	The Cloud	15
2.2.5	Augmented Reality/Virtual Reality	15
2.2.6	Mobile Technologies	15
2.2.7	Pervasive and Personalized Healthcare	18
2.2.8	Biosensors and Bioelectronics on Smartphones	18
2.3	Smart Healthcare Applications and Products	18
2.3.1	Assistance with Diagnosis and Treatment	18
2.3.2	Health Management	18
2.3.3	Disease Prevention and Risk Monitoring	19
2.3.4	Virtual Assistants	19
2.3.5	Smart Hospitals, Rooms and Homes	19

2.3.6	Assistance with Drug Research	19
2.3.7	Telemedicine/Telehealth	19
2.4	Positive and Negative Effects of Technology.	19
	References.	20
3	Telehealth.	23
3.1	What Is Telehealth?	23
3.2	The Needs and Goals of Telehealth.	24
3.3	Telemedicine Trends	25
3.4	Issues Related to Telehealth.	25
3.5	Differences Between Telemedicine, Telecare and Telehealth	25
3.6	Examples and Uses of Telehealth and Telemedicine.	26
3.7	Telemedicine Apps.	27
3.8	Technology Requirements in Telemedicine.	27
3.9	Features and Functionality of Telehealth Apps	29
3.10	Setting Up a Telemedicine Program	30
3.10.1	Step 1: Select the Platform(s)	30
3.10.2	Step 2: Design an Appropriate App	31
3.10.3	Step 3: Choose APIs to Integrate into the App	32
3.10.4	Step 4: Test the App and Perform Quality Assurance	33
3.10.5	Step 5: Deploy and Maintain the App	33
3.11	Potentials and Limitations of Telehealth	33
	References.	34
4	Algorithms and Software for Smart Health	37
4.1	Software for Telehealth	37
4.1.1	Security Regulations and Laws	37
4.1.2	Technology Stack for Telehealth App Development	38
4.1.3	Technologies Used in Telehealth Apps	39
4.1.4	Guidelines for Building a Telehealth App	39
4.2	Softermii: Smart Healthcare App Development	40
4.2.1	HIPAA Video	40
4.2.2	Near Pharmacy.	40
4.2.3	PetRealTime.	40
4.2.4	Telehealth Apps and WebRTC	41
4.2.5	mHealth Apps.	41
4.2.6	IoT Firmware	41
4.2.7	Medical Enterprise Apps	41
4.2.8	Health Insurance Management	41
4.2.9	Healthcare Data Security and Privacy Compliance.	41
4.2.10	Blockchain Ledger and EHRs	42
4.3	Practice Management Solutions: Medical Practice Management Software.	42
4.4	Problem-Specific Medical Algorithms Used in Smart Health.	43
4.4.1	Virtual Visit Algorithm for COVID-19 Patients.	43
4.4.2	Telehealth Algorithm for Management of Dizzy Patients	43

4.4.3	QRS Detection Algorithm for Telehealth ECG Recordings .	43
4.4.4	Other Medical Algorithms	44
4.5	Algorithms Used to Transform Healthcare	44
4.5.1	Fourier Transform	44
4.5.2	TCP/IP	44
4.5.3	RSA Encryption Algorithm	44
4.5.4	MUMPS	44
4.5.5	Probabilistic Data-Matching Algorithm.	45
4.5.6	BLAST.	45
4.5.7	Neighbour-Joining Algorithm	45
4.5.8	Medical Algorithms	45
4.5.9	Health Scores	45
4.5.10	Big Data Analytics Tools and Techniques	45
4.5.11	Quantum Algorithms	46
4.5.12	Bioinformatics Tools for Medical Image Processing and Analysis.	46
4.5.13	Data Science Approaches.	46
4.5.14	AI and ML Approaches	46
	References.	47
5	Scalable Smart Health Systems	49
5.1	Scalable and Emerging Smart Healthcare Systems	49
5.1.1	IBM Watson	49
5.1.2	Open mHealth	51
5.1.3	Health Decision Support Systems	52
5.1.4	SoDA Stress Detection and Alleviation System	53
5.1.5	Energy-Efficient Health Monitoring System.	53
5.2	Secure and Scalable Architecture Using Mist Computing.	54
5.3	Large-Scale Distributed Computing in Smart Healthcare	54
5.4	Scalable Cognitive IoT–Based Smart City Network Architecture.	55
5.5	Cloud-Enabled WBANs for Pervasive Healthcare.	55
5.6	Blockchain-Based Distributed Architecture for a Scalable Smart City Network.	56
5.7	Edge Computing for Scalable Smart Health	56
5.8	Structural Health Monitoring System for a Scalable Smart Sensor Network.	56
5.9	Fog Computing for Scalable Smart Healthcare	56
	References.	57
6	Devices, Systems and Infrastructures for Smart Health	61
6.1	Smart Health Infrastructures	62
6.1.1	Smart Healthcare Infrastructure Challenges	64
6.2	Smart Healthcare Structures	65
6.2.1	Protective Systems	66
6.2.2	Preventive Systems	66

6.2.3	Responsive Systems.....	66
6.2.4	Medical Automation Systems	66
6.3	Smart Healthcare Devices	67
6.3.1	Sensor-Based Smart Healthcare Devices.....	67
6.3.2	Smartphone-Based Smart Healthcare Devices	68
6.3.3	Microcontroller-Based Smart Healthcare Devices	68
6.3.4	IoT/IoMT/Sensor-Based Healthcare Devices	68
	References.....	69
7	Cyber-physical Systems for Healthcare	71
7.1	Necessity of CPSs	72
7.2	CPS Standards	73
7.2.1	Standard Model to Synergic Model.....	73
7.2.2	Distinctive and Conceptual Realization Characteristics of CPSs	74
7.3	CPS Architecture	74
7.4	Technologies Related to CPSs	75
7.4.1	Advances in Macro-robotic Technologies	76
7.4.2	Synergic Technologies	76
7.5	Benefits and Applications of CPS	79
7.5.1	Automobiles and Transportation	79
7.5.2	Healthcare and Medicines	79
7.5.3	Manufacturing	80
7.5.4	Security and Surveillance	80
7.5.5	Power and Thermal Energy Management	81
7.5.6	Smart Homes and Buildings	81
7.5.7	Construction.....	81
7.6	CPSs for Healthcare (CPSsH)	82
7.7	CPSs Issues and Challenges.....	82
7.7.1	Software Consistency.....	83
7.7.2	Medical Device Interactions	83
7.7.3	Data Mining.....	83
7.7.4	Privacy and Security	84
7.7.5	Program Response	84
7.7.6	Processing of Complex Queries.....	84
7.7.7	Absence of a Prototype Structure	84
7.8	CPSs and Future Medical Devices.....	85
	References.....	86
8	Big Data Analytics and Cognitive Computing in Smart Health Systems	87
8.1	Big Data Analytics.....	89
8.1.1	Characteristics of Big Data	89
8.1.2	The ‘Four V’s’ of Big Data Analytics in Healthcare	90
8.1.3	Architecture of Big Data Analytics in Healthcare	91

8.1.4	Process of Big Data Analytics	91
8.1.5	Need for Big Data in Healthcare	93
8.1.6	Big Data Framework for Smart Healthcare	93
8.1.7	Big Data Applications for Healthcare	94
8.2	Cognitive Computing for Healthcare	94
8.2.1	Cognitive Analytics Architecture	95
8.3	Healthcare and Data Management Role Players	96
8.4	Impact of Cognitive Computing Systems on Healthcare	97
8.5	Smart Healthcare Approaches	97
8.6	Big Data Challenges in Healthcare Systems	98
8.7	Big Data and Cognitive Technology Future Plans for Healthcare	98
	References	99
9	Values and Risks Associated with Smart Health	101
9.1	Goals of Smart Health Systems	103
9.2	Principles of Smart Health Systems	104
9.3	Classification of Smart Healthcare	105
9.4	Smart Health System Essentials	105
9.5	Security Requirements of Smart Healthcare	107
9.6	Major Risks Related to Smart Healthcare	109
9.7	Security Solution of Smart Health Applications	109
9.8	Smart Health System Services	109
	References	110
10	Challenges, Opportunities and Future Trends in Smart Health	113
10.1	Challenges in Adoption of Smart Healthcare Systems	115
10.1.1	Collection or Gathering Information	115
10.1.2	Storage and Recovery of Data	116
10.1.3	Knowledge Acquisition	117
10.1.4	Smart Healthcare Applications	117
10.2	Transformational Challenges for Smart Healthcare Centres	117
10.2.1	Systems for Patient Monitoring in Smart Healthcare Systems	118
10.2.2	Data Accuracy in Smart Healthcare Systems	118
10.2.3	Cyber-security in Smart Healthcare Systems	118
10.2.4	Reducing the Costs of Devices and Sensors in Smart Healthcare Systems	118
10.2.5	Data Processing and Validation in Smart Healthcare Systems	119
10.2.6	Tuning and Interoperability of Smart Healthcare Systems	119
10.3	Opportunities in Smart Healthcare	119
10.3.1	Remote Monitoring	120
10.3.2	Chronic Self-Management	120
10.3.3	Performance Improvement	120

10.3.4	Behaviour Modification	120
10.3.5	Detection and Diagnosis	121
10.4	Trends Shaping the Future of Smart Healthcare	121
	References.	124

About the Authors



Sonali Vyas has worked as an academician and researcher for a decade. She is currently working as an assistant professor (Selection Grade) at the University of Petroleum and Energy Studies in Dehradun (Uttarakhand, India). She is a professional member of the Computer Society of India (CSI), the Institute of Electrical and Electronics Engineers (IEEE), the Association for Computing Machinery (ACM) India, the Institute For Engineering Research and Publication (IFERP), the International Association of Engineers (IAENG), the Internet Society (ISOC) and the Society for Clinical Research Sites (SCRS). She has authored numerous research papers, articles and chapters in refereed journals, conference proceedings and books. She co-edited the books *Pervasive Computing: A Networking Perspective and Future Directions*, published by Springer Nature, and *Smart Farming Technologies for Sustainable Agricultural Development*, published by IGI Global. She has acted as a guest editor for a special issue on Machine Learning and Software Systems in the *Journal of Statistics & Management Systems* (JSMS), published by Thomson Reuters. She is an editorial board member and reviewer board member for many refereed national and international journals. She has served as an active member of the organizing committees, national advisory boards and technical program committees at many national and international conferences. She has also chaired sessions at various reputed national and international conferences. In 2018, Dr Vyas received the Best Academician of the Year Award (Female) in the Global Education and Corporate Leadership (GECL) awards. In 2021 she also received “the National

Distinguished Educator Award 2021”, instituted by the International Institute of organized Research (I2OR) which is a registered MSME with the Ministry of Micro, Small and Medium Enterprises, Government of India. She is also supervising PhD and M.Tech scholars in her area. Her research interest includes Data Virtualization, Data Analytics, Data Mining and Healthcare System Informatics.



Deepshikha Bhargava has rich experience of more than 20 years as an academician. She currently works as a professor in the School of Computer Science at the University of Petroleum and Energy Studies in Dehradun (Uttarakhand, India) and is the presiding officer for the Internal Complaints Committee at the university. She previously served as a visiting professor at the Université des Mascareignes (UDM), Ministry of Education and Human Resources, Tertiary Education and Scientific Research, in Mauritius. She is a member of the Institute of Engineers (IE), the Association for Computing Machinery's Council on Women in Computing (ACM-W), the Institute of Electrical and Electronics Engineers (IEEE), the US Computer Science Teachers Association (CSTA), the Computer Society of India (CSI), the Project Management Institute (PMI), the Indian Society of Lighting Engineers (ISLE) and Vigyan Bharti (VIBHA). She has published 16 Books & 14 book chapters, edited 02 books and published 60+ research papers in journals and conference proceedings. Prof. Bhargava has previously received the Active Participation (Woman) Award and the Best Faculty of the Year award under the sub-category 'Authoring Books on Contemporary Subjects', among others. She also received an award from the Ministry of Human Resource Development (MHRD), Government of India, in 1992 for academic excellence. Overall 04 PhDs completed under her guidance. At present supervising three scholars as guide/co-guide. Her Research thrust areas are Artificial Intelligence, Soft computing, Bio-inspired computation and Healthcare informatics.

Smart Health: An Introduction

1

समदोषः समाग्निश्च समधातुमलक्रियः ।
प्रसन्नात्मेन्द्रियमनाः स्वस्थ इत्यभिधीयते ।।

Samadoshaha samaagnischa samadhaatumalakriyaha I
Prasannaatmendriyamanaaha swastha ityabhidheeyate II

Sushruta Samhita – Sutra Sthana – 15:41 (1500 BC)

In the second century BC, the *Sushruta Samhita* text offered the most comprehensive explanation of health. A similar definition of health, given by the World Health Organization (WHO) in 1948, states that:

health is a state of complete physical, mental and social well-being and not merely an absence of disease or infirmity.

There is no doubt that health has always been considered the most important measure of our life and has a symbolic relationship with other parts of our life. A healthy body and healthy mind signify a healthy life. The emergence of technologies has influenced many parts of our daily life, including healthcare. Technological advances now underline all dimensions of healthcare, including outdoor activities, home care, in-hospital healthcare and personal healthcare, to name just a few. Information and communications technology (ICT) plays an important role in improving the quality of healthcare from traditional healthcare to smart healthcare [1].

With increases in the population, traditional healthcare now finds it difficult to provide adequate solutions for its stakeholders. The coronavirus disease 2019 (COVID-19) pandemic has now made us all even more aware of the pressures imposed on healthcare management, and these concerns are globally the same in both developed countries (such as the UK and the USA) and developing countries (such as India). Although developed countries have outstanding health frameworks

and medical facilities, and cutting-edge technologies, they are still not able to deal with such a pandemic. The situation in developing countries with large populations is much more critical.

The major issues encountered during the COVID-19 pandemic include disease prevention, creation of awareness among citizens, diagnosis of COVID-19 patients, provision of proper treatment, bed management in hospitals, the care of COVID-19 patients, prevention of coronavirus anxiety, management of healthcare services, vaccine development and distribution, and—above all—management of shortages of supplemental oxygen supplies.

The present status of traditional healthcare systems and their contributions to the COVID-19 pandemic situation give us enough reasons to replace traditional healthcare with smart healthcare.

In this chapter, readers will gain understanding of the concepts of smart health and allied areas—such as electronic health (eHealth), digital health, mobile health (mHealth), and telehealth—and the significance of each of them. The chapter concludes with a discussion of the framework and various components of smart healthcare.

1.1 What Is Smart Health?

Smart health is use of various technological advances and gadgets to provide better services for patients, hospitals, doctors and health workers. In other ways, it provides better care in the dimension of health, usually termed *smart healthcare*.

The key concepts in smart healthcare include eHealth and mHealth services, electronic record management, smart home services, and intelligent and connected medical devices.

According to Blue Stream Consultancy [1]:

smart healthcare is defined by the technology that leads to better diagnostic tools, better treatment for patients, and devices that improve the quality of life for anyone and everyone.

The healthcare services provided by smart healthcare include [2]:

- Smart gadgets and medical wearables (such as the Fitbit and smartwatches)
- Smart healthcare products and monitoring devices (such as digital thermometers, smart glucometers and blood pressure monitors)
- The Internet of Medical Things (IoMT), wireless networks, body area networks and extensive area networks
- Smartphones and smart mobile applications (apps) for fitness, nutrition, hygiene and healthcare
- Smart devices for the elderly (hearing aids, toilet aids, walking aids, global positioning system (GPS) tracker shoe inserts etc.)
- Smart devices for persons with special needs (smart home help, smart sticks for the blind and partially sighted community, hands-free voice communication, speech to text etc.)