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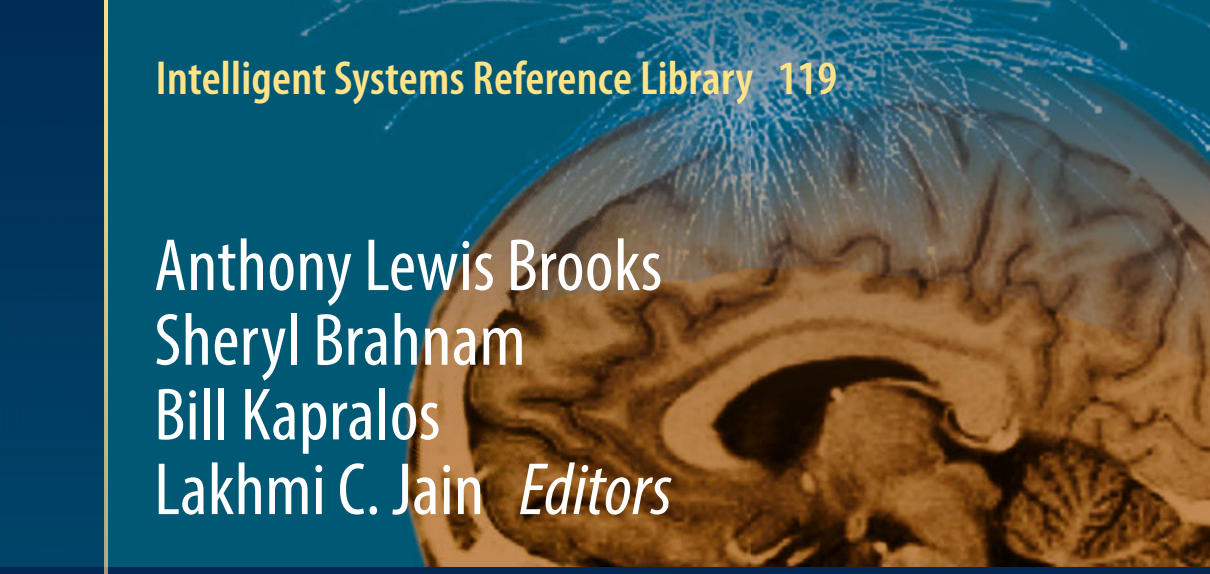

Anthony Lewis Brooks
Sheryl Brahnam
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Lakhmi C. Jain *Editors*

Recent Advances in Technologies for Inclusive Well-Being

From Worn to Off-body Sensing, Virtual Worlds, and Games for Serious Applications

Springer

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Volume 119

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Foreword

We are being bombarded with messages of doom about our inability to deliver the required level of healthcare. In the western world we are currently experiencing an increase in life expectancy but not necessarily of years of active life. Thanks to advances in medicine and public health, babies can survive being born at an early stage of gestation and those with a condition who would not have survived long past birth are living into middle age and beyond. The consequent challenge to our health care systems is not restricted to the western world. Less developed countries have been the first to suffer from the effects of climate change and virulent pandemics and frequently live long distances from health services.

Luckily, innovators have been pointing out that the solution is not just "more of the same" but is to be found in radically different ways of solving the problem. The astounding rate of change caused by more recent technological developments has enabled us to do more things faster but has also had more profound changes on old models of delivery. After a period of being astounded by the rate of development of digital technology, we are now witnessing its transition into a qualitatively different era. Whereas many of the original developments were very much fixed in physical space, tethered to a desktop computer, miniaturisation and mobile technology has moved on from the need to be located in one space and ownership is passing from the hands of experts. This in turn has led to the binary between experts and the rest of us becoming fuzzy. Taken further, this could result in a redistribution of power and devolvement of knowledge.

This collection of chapters from a wide range of disciplines, illustrates the march of digital technology out of the laboratory and out of the hands of the experts to be located in the end users' own space. Head mounted VR displays mean that they can be accessed where and when the user wishes and, in the case of a therapeutic application, the user can take back control of their own rehabilitation.

And it's not just this boundary that is being broken down. It is also possible that in addition to challenging the location of expertise, new technology will challenge the binary conception of health versus illness and disability versus lack of disability. The concept of assistive technology started off being seen as something created for

people with a disability by others such that it enabled them to achieve a function previously denied to them. Wheelchairs could be seen to act as exemplars but however much we tinkered with their design and appearance, they marked the owner out as different, disabled as against able bodied and could contribute to their stigmatisation.

The phenomenon that the editors refer to as "an ecosystem that encompasses such tools as microcontrollers, sensors for just about everything, and personal 3D printing" stands to challenge this stigmatisation. Using a smartphone to remind you in which order to carry out self care procedures no longer marks you out as different if everyone around you is also holding a smartphone. Hearing aids do not look so unusual when every other person you pass in the street is wearing high end headphones for their smart device.

Mention of hearing aids reminds me that almost two decades ago, there was speculation (Cromby and Standen 1999) about the parallels between using assistive devices such as wheelchairs and being a cyborg. Cyborgs were originally the stuff of science fiction, Robocop type characters whose physical abilities were extended beyond normal human limitations by mechanical elements built into their bodies. However, in a 2014 article on the BBC Future website http://www.bbc.com/future/story/20140924-the-greatest-myths-about-cyborgs.

Frank Swain used this concept to describe his use of a hearing aid: "So I am now a cyborg out of necessity, not choice. Being part machine is my resting state".

This use of the term illustrates how technology could soon end the binary distinction between being disabled and being described as able bodied. Kevin Warwick, Professor of Cybernetics at Reading University Warwick installed a microchip in his arm that allowed him to operate doors, lights, heaters and other computers remotely as he moved from room to room. He wasn't seeking to supplement any identified lack of ability but I bet he was able to move around the environment much more easily when carrying a cup of coffee. Think what an advantage such a microchip could give someone who uses a wheelchair or other mobility device that required the use of their hands. In chapter 10 participants wore a vibrotactile vest that transmitted the heart beats and respiration rates of the vest wearers to a public display (the "wall") and any tactile stimuli applied to the wall were transmitted back to the vest wearer whenever the wall is swiped or knocked upon, these stimuli are vibrotactically transmitted to the vest wearers. Having achieved this, it is only a small step to developing smart wearables that look no different from normal clothing. Use of them would not mark you out as different and their employment could support the wearer in a whole range of activities from just making our day to day activities easier to providing prompts to those whose cognition has deteriorated.

At first sight, this innovation seems to be revolutionary, new and exciting but, as illustrated by our concept of cyborgs, the merging of human and technology has been going on for centuries. Transhumanism is a cultural and intellectual movement that believes we can, and should, improve the human condition through the use of advanced technologies. In the forward to their book *The Transhumanist Reader* (2013) More and Vita-More see transhumanism as promoting an interdisciplinary

approach to understanding and evaluating the opportunities for enhancing the human condition and the human organism opened up by the advancement of technology.

After reading the contributions to this volume, some of you will be inspired to take some of them forward. However, it is equally important for us to read about these developments and reflect on their implications in terms of the human condition. At least two of the contributors raise potential concerns about these innovations. In the words of More and Vita-More "The same powerful technologies that can transform human nature for the better can also be used in ways that, intentionally or unintentionally, cause direct damage or more subtly undermine our lives". It was ever thus: no advances have come without the potential for harm. That has never stopped us from moving forward.

Penny Standen is Professor in Health Psychology and Learning Disabilities at Nottingham University. Her main area of research is developing and evaluating new technologies, robotics, multimedia and gaming for people with intellectual disabilities to help the acquisition of independence skills and improve cognition and quality of life. This work has resulted from collaboration with computer scientists and the involvement of users at all stages of the research process.

Prof. Penny Standen
Nottingham University, UK

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Preface

This preface briefly introduces Recent Advances in Technologies of Inclusive Well-Being: Wearables, Virtual Interactive Spaces (VIS)/Virtual Reality, Authoring tools, and Games (Serious/Gamification). The book, which builds upon an initial Springer volume focused on technologies of inclusive well-being, came about through the amassed positive response attributed to the earlier publication edited by the first three co-editors herein. Inclusive well-being would seem a hot topic and as associated technologies continue to advance alongside adoptions and applied practices, it was clear the demand to expand to include topics as per title. Virtual worlds and games for serious applications is a growing field and this is a reason behind the book, the editors' motivation, the subject matter chosen, and its scope and aims to impact the field and associated. The earlier book's metrics, at time of writing, is near ten thousand downloads and progressively increasing citations. Readers of the first volume will notice an additional co-editor to the team in the form of Associate Professor Bill Kapralos from the University of Ontario Institute of Technology, Canada: It is a pleasure to have Bill onboard and his chapters are an important contribution.

The publication covers wide ground as introduced in the first chapter. Authors covering a gamut of disciplines come together under the inclusive well-being theme and it is anticipated that there is something for everyone, be they academic, student, or otherwise interested party. The main aim of the book is to disseminate this growing field through a combined effort that predicts to inform, educate, evoke—or even provoke, at least in thought—responses and discussions. While not the sole purpose, the editors along with the authors believe it important to bring such work presented out from behind the walls of establishments into the public specter so as to impact from a societal level.

The challenge of bringing together a collection of seminal work relating to technology subject of encroachment is just that—things move fast. We have been aware of this challenge and need to publish a contemporary volume within a schedule considering the prerequisite for up-to-date(ness) of presented research. The initial timeline had to be extended due to counterbalancing to the editors' different time zones, work and family commitments, and busy lives and distractions

of the real world—for the delay we apologize to authors. However, in stating this, we believe that the extension has resulted in an even stronger contribution, realized in a form to credit all involved.

Acknowledgements are given to all authors for their submitted works and patience and understanding in the editorial team's challenges to realize what is anticipated as an impactful volume. We thank Springer's publishing team for their input to realize the volume. The editors thank their own families whose tolerance in supporting us in tackling such endeavors to publish is often tested; we are indebted for their support. The last acknowledgement is given to you, the reader, who we thank for coming onboard from your specific individual perspective; in thanking you for the interest in the work, we anticipate your curiosity being stimulated by individual texts so as to read not only chapters labeled in line with your position but also to stray and explore chapters not aligned to your discipline. In line with this latter statement, we offer no suggestions about how to read the book; there is no special structure, however, contents are split to theme in order to assist your reading adventure.

In closing we, the editors, extend our warmest regards encouraging you to explore the texts herein toward whetting your appetite to then dive further into the body of work and possible being stimulated to even visit the earlier volume—enjoy!

Best wishes from the team
Sheryl, Lakhmi, Bill and Anthony (aka Tony)

Contents

About the Editors

Dr. Anthony Brooks is Associate Professor at Aalborg University, Denmark where he is director/founder of the "SensoramaLab". He was a founding team-member of the Medialogy education wherein he is section leader, lecturer, coordinator, supervisor, and study board member. Originating from Wales, he created a bespoke volumetric invisible sensing system for unencumbered gesture-control of media to stimulate interactions and thus, human performance potentials. Initially titled Handi-MIDI, in the mid 1990's he renamed the maturing body of work as SoundScapes. Virtual Worlds for creative expression, Games for Serious Applications, and Virtual Interactive Space (VIS) are core aspects of his human-centered research targeting alternative channeling of biofeedback to realize human afferent-efferent neural feedback loop closure as a supplement for traditional rehabilitation, healthcare, and Quality of Life interventions. Making music, digital painting and robotic light control via available function/residual movements are selectable. He originated the ZOOM model (Zone of Optimized Motivation) for in-action intervention and an on-action analysis and assessment model under a custom-made synthesized methodology of Action Research integrated with Hermeneutics—resulting the Recursive Reflection model.

He has approximately 200 publications. His research is responsible for—sizable externally funded national and international (European) projects; –a games industry start-up, and patented commercial product (Patent US6893407 "Communication Method and

Apparatus"). He is acknowledged as a third culture thinker and "world pioneer in digital media and its use with the disabled community". He is an active keynote speaker at international events and has presented SoundScapes globally (including The Olympics and Paralympics 1996/2000 and numerous others). His work targets societal impact and benefit in respect of future demographics and service industries through applied ICT and optimized motivation of system use through inclusive intervention strategies: He is an ambassador for accessibility. He is Danish representative for UNESCO's International Federation for Information Processing (IFIP) Technical committee (WG14) on "Entertainment Computing"– specifically under work groups WG14.7 "Art and Entertainment"; WG14.8 "Serious Games", and WG 14.9 "Game Accessibility". He is appointed by the European Commission as EU expert examiner, rapporteur, (Serious Games/Gamification, Human-Computer Confluence, Presence and Future Emerging Technologies) and panel reviewer of funded projects (e.g. Presenccia – an Integrated Project funded under the European Sixth Framework Program, Future and Emerging Technologies (FET), Contract Number 27731). As vice-chair of the European Alliance for Innovation's Wellbeing (SIB-WellB) Market Trends and Society segment, he is also steering person for the international conference "ArtsIT, Interactivity and Game Creation". He achieved his PhD under the University of Sunderland, Great Britain.

Dr. Sheryl Brahnam is the Director/Founder of Missouri State University's infant COPE (Classification Of Pain Expressions) project. Her interests focus on face recognition, face synthesis, medical decision support systems, embodied conversational agents, computer abuse, and artificial intelligence. Dr. Brahnam has published articles related to medicine and culture in such journals as *Artificial Intelligence in Medicine, Expert Systems with Applications, Journal of Theoretical Biology, Amino Acids, AI & Society, Bioinformatics, Pattern Recognition, Human Computer Interaction, Neural Computing and Applications, and Decision Support Systems.*

Dr. Bill Kapralos is an Associate Professor in (and Program Director of) the Game Development and Entrepreneurship Program at the University of Ontario Institute of Technology. His current research interests include: serious games, multi-modal virtual environments/reality, the perception of auditory events, and 3D (spatial) sound generation for interactive virtual environments and serious games. He has led several large interdisciplinary and international serious gaming research projects that have included experts from medicine/surgery, and medical education with funding from a variety of government and industry sources. He is currently leading the serious gaming theme within the *Social Sciences and Humanities Research Council of Canada* (SSHRC) Interactive and *Multi-Modal Experience Research Syndicate* (IMMERSe) initiative. Bill chaired the 2014 *IEEE Games, Entertainment, and Media* (GEM) conference, and the *ACM FuturePlay International Conference on the Future of Game Design and Technology* from 2007-2010. He co-chaired the 2015 IEEE GEM conference, and the *ACM Virtual Reality Software and Technology Conference* in 2012. He is a past recipient of an IBM Centers for Advanced Studies Faculty Award, a past co-recipient of a Google Faculty Award, and a past recipient of a *Natural Sciences and Engineering Research Council of Canada* (NSERC) and *Japan Society for the Promotion of Science* (JSPS) Fellowship to conduct research in Japan. He recently completed a two-month stay at Shizuoka University in Hamamatsu, Japan, as a Visiting Research Fellow and Guest Professor as part of this Fellowship.

Lakhmi C. Jain BE (Hons), ME, PhD Fellow (Engineers Australia) is with the Faculty of Education, Science, Technology & Mathematics at the University of Canberra, Australia and Bournemouth University, UK.

Professor Jain founded the KES International for providing a professional community the opportunities for publications, knowledge exchange, cooperation and teaming. Involving around 10,000 researchers drawn from universities and companies world-wide, KES facilitates international cooperation and generate synergy in teaching and research. KES regularly provides

networking opportunities for professional community through one of the largest conferences of its kind in the area of KES www.kesinternational.org

His interests focus on the artificial intelligence paradigms and their applications in complex systems, security, e-education, e-healthcare, unmanned air vehicles and intelligent agents.

Chapter 1
An Overview of Recent Advances in Technologies of Inclusive Well-Being

Anthony Lewis Brooks, Sheryl Brahnam, Bill Kapralos and Lakhmi C. Jain

Abstract This chapter reflects on luminary work on the use of digital media for the therapeutic benefit and well-being of a wide range of people. It also discusses the importance of multidisciplinarity, end user participation in design, and the future of new technologies of inclusive well-being. A summary of the chapters included in this book is also presented.

Keywords Alternative realities · Serious games · Rehabilitation · Therapy · Virtual environments · CVAA · Multidisciplinarity · Ethics · Multimodal sensory environments

1.1 Introduction

This book is the second volume on the "Recent Advances in Technologies of Inclusive Well-Being" and is published under the Intelligent Systems Reference Library. The first volume was published in a series under the umbrella of Springer's

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''Studies in Computational Intelligence'' (SCI) portfolio that brings together the topics of serious games, alternative realities, and play therapy.

The focus on this specific sequence of volumes is to share luminary work on the use of digital media for the therapeutic benefit and well-being of a wide range of people—spanning those with special needs to the elderly to entire urban neighborhoods. This book builds upon the first volume to further bring together these topics to demonstrate the increasing trans/inter/multi-disciplinary initiatives apparent today in science, medicine, and academic research—interdisciplinary initiatives that are already profoundly impacting society. In line with this, the editors believe it important to promote the transcending of what is researched, developed and realized behind the walls of academia into applied societal bearing for the benefit of individuals and communities. This second volume thus shares such work reflecting contemporary impactful designs, learning/practices, and innovations in physical therapies and multimodal experiences.

As was pointed out in the foreword in the previous volume, the last decade has presented a dramatic increase in the global adoption of innovative digital technologies. This can be seen in the rapid acceptance and growing demand for high-speed network access, mobile devices/wearable displays, smart televisions, social media, hyper realistic computer games, novel interactions, and numerous behavioral sensing devices. There are new ways to sense the world around us with alternative reality (virtual reality, augmented reality, mixed reality, and so on—) devices and content becoming available at affordable prices for all with related software tools available for creating one's own content without the need for academic background or complex laboratory facilities. Thus, consumer-driven and consumer-created interactive technologies have truly arrived and evolved beyond a simple maker-movement to now realize an ecosystem that encompasses such tools as microcontrollers, sensors for just about everything, and personal 3D printing, and so on—. These advances in technology enable a driving of innovation in manufacturing, engineering, industrial design, hardware technology and education for benefitting society. This volume thus presents work by ingenious 'makers/creators' utilizing innovative technologies toward investigating well-being and quality of life across differences of ability, age, and situation.

It is clear from these texts that what is being witnessed in the fields targeted is that healthcare researchers, providers, and related professionals, have adopted customizable (i.e., made for task) and adapted (i.e., not made for task) systems, apparatus, and methods. Advent of new game control interfaces, commercially available since the first decade of the twenty-first century, has probably had greatest impact in such adoption. Such systems have contextual added value in that whilst being known to many end users through home use, data can be generated of the human input that informs treatment programmes and other interventions. Software that enables generic use (vis., specific to game platforms) is commonly available so

that the interface devices can capture human input and map to desired content that can be tailored for each individual, task, and situation. Analysis tools are also used to support progressions in design and re-design iterations and thus optimally support progressions. However, such work is ongoing with numerous challenges innate to the genre. Such challenges include how to optimize accessibility and inclusion, and this is partly addressed via development of (and upon) the United States Twenty-First Century Communications and Video Accessibility Act (CVAA), as pointed out in this volume by the lead editor's contribution. Thus, the emergence and growing adoption of clinical applications that both leverage off-the-shelf technology and push the boundaries of new technologic development should eventually benefit from enforcement of the act such that home-training is increasingly accessible for 'all'. As professor Skip Rizzo stated in his foreword to the first volume—"electric typewriters gave way to word processors and handwritten letters to email, we are now witnesses to a wave of technological innovation that is driving how healthcare is accessed and delivered, and how clinical users engage with it". With increased technology 'buy-in' by the general public such that most have a powerful personal computer that can link to a home-based entertainment system, home-based activities using such technological apparatus and methods as presented herein suggest optimization toward supporting self-responsibility for healthcare, well-being and quality of life aligned with what this volume presents.

The context and content of the series in the form of the two volumes published to date offers much to digest for a variety of readers from scientists, academics, and students, to healthcare professionals, providers, and end-users. In this context end-users are important due to the availability, affordability and usability of the current spate of systems and adaptations on the market. Whilst the CVAA is currently targeting the United States, it is envisioned by the editors that it is a first step in making visible issues on accessibility and inclusion that should be addressed globally for the benefit of the majority. We, the editors, envision continued implementations, developments and improvements of such acts that will support the accessibility and inclusion argument that certain industries have avoided addressing focusing instead solely on the economic strategies that target the maximum financial gain versus maximum human benefit.

We strongly support and wish to reiterate in this Introduction what Rizzo stated in his foreword to the first volume:

> While 20 years ago the title, ''Technologies of Well-Being: Serious Games, Alternative Realities, and Play Therapy'', would raise the specter of Star Trek, Lawnmower Man, and Super Mario Brothers, in the current context it instead evokes a sense that new possibilities are within our reach as we harness technology to create user experiences that promote human well-being. The use of games and simulation technology and play for engaging users with health care has passed through its initial phase of scientific doubt and quizzical skepticism. These concepts are now seen as vibrant options that bring together both art and science for a useful human purpose. No longer seen as harebrained schemes, we see respected scientific journals like Nature, American Psychologist, and JAMA publishing research that probes these concepts. Papers in this area are routinely presented at

> long-established scientific venues in addition to the more specialized homegrown conferences that our community has now evolved. Major funding agencies are now earnestly supporting R&D in these areas. And, when you describe what you do for a living to your neighbor, they get it right away and seem genuinely impressed! In essence, the science and technology has caught up with the vision in clear and demonstrative ways.

This second volume is entitled "Recent Advances in Technologies of Inclusive Well-Being: Wearables; Virtual Interactive Spaces (VIS)/Virtual Reality; Emotional Robots; Authoring tools; and Games (Serious/Gamification)." It evolves the first volume in part through the title's expansion of topics to reflect current trends and activities.

The first volume in this series had sections on (1) *Technologies for Rehabilitation* —including titles such as "Design Issues for Vision-Based Motor-Rehabilitation Serious Games"; "Development of a Memory Training Game"; "Assessing Virtual Reality Environments as Cognitive Stimulation Method for Patients with MCI"; "Adaptive Cognitive Rehabilitation"; "A Body of Evidence: Avatars and the Generative Nature of Bodily Perception"; "Virtual Teacher and Classroom for Assessment of Neurodevelopmental Disorders"; "Engaging Children in Play Therapy: The Coupling of Virtual Reality Games with Social Robotics"; (2) *Technologies for Music Therapy and Expression*—including titles "Instruments for Everyone: Designing New Means of Musical Expression for Disabled Creators"; "Designing for Musical Play"; (3) *Technologies for Well-Being* —including titles "Serious Games as Positive Technologies for Individual and Group Flourishing"; "Spontaneous Interventions for Health: How Digital Games May Supplement Urban Design Projects"; "Using Virtual Environments to Test the Effects of Lifelike Architecture on People"; (4) *Technologies for Education and Education for Rehabilitative Technologies*—including titles "An Overview of Virtual Simulation and Serious Gaming for Surgical Education and Training"; "The Ongoing Development of a Multimedia Educational Gaming Module"; and the final section, (5) *Disruptive Innovation*—with a single title of "Disruptive Innovation in Healthcare and Rehabilitation". This second volume furthers through contributions relating to Wearables; Virtual Interactive Spaces (VIS)/Virtual Reality; Emotional Robots; Authoring tools; and once again Games (Serious/Gamification). It is clear from the texts in both volumes to date that the field has many perspectives and can be considered as multidisciplinary, interdisciplinary, and transdisciplinary. Whilst these terms are increasingly used in the literature, they are ambiguously defined and interchangeably used.

Choi and Pak [1] state that "Multidisciplinarity draws on knowledge from different disciplines but stays within their boundaries. Interdisciplinarity analyzes, synthesizes and harmonizes links between disciplines into a coordinated and coherent whole. Transdisciplinarity integrates the natural, social and health sciences in a humanities context, and transcends their traditional boundaries. The objectives of multiple disciplinary approaches are to resolve real world or complex problems, to provide different perspectives on problems, to create comprehensive research questions, to develop consensus clinical definitions and guidelines, and to provide comprehensive health services.'' He states further that "The three terms refer to the

involvement of multiple disciplines to varying degrees on the same continuum. The common words for multidisciplinary, interdisciplinary and transdisciplinary are additive, interactive, and holistic, respectively."

1.2 Contributions in This Book

The chapters in this book are divided into five parts that reflect major reviews and themes in recent advances in technologies of inclusive well-being:

Part 1: Literature Reviews and Taxonomies
Part 2: Physical Therapy
Part 3: Touch and Wearables
Part 4: Special Needs
Part 5: Ethics and Accessibility

Below we provide a synopsis of each of the chapters in this book.
Part 1: *Literature Reviews and Taxonomies*
In Chap. 2, entitled "An Overview of Serious Game Engines and Frameworks," Brent Cowan and Bill Kapralos examined the tools (game engines and frameworks) that are commonly used to develop serious games. They present the results of two surveys that were conducted to determine the most widely used tools for serious game development and summarize their features. The motivation for this review is to provide those seeking tools to develop serious games with the appropriate knowledge and insight regarding the tools that are currently available to them so that they can make an informed decision. The chapter ends with a brief discussion regarding a framework that Cowan and Kapralos are currently developing specifically for the development of serious games that aims to strike a balance between ease of use and functionality, while providing the user with the necessary options and tools to ideally develop effective serious games.

In Chap. 3, "A Review of and Taxonomy for Computer Supported Neuro-Motor Rehabilitation Systems," Lucas Stephenson and Anthony Whitehead, as the title of the chapter suggest, provide a review of the literature of computer supported neuro-motor rehabilitation. Unlike other forms of physical therapy rehabilitation that focus on rebuilding muscle strength and flexibility, neuro-motor rehabilitation rebuilds and strengthens neural pathways to affected motor systems. As nuero-motor rehabilitation requires intense repetition of therapeutic exercises that lead to cognitive fatigue, research into computer supported systems and serious games has grown considerably the last couple of decades. The focus of the chapter, however, is primarily on providing a taxonomy for organizing the literature, a taxonomy that is carefully developed and validated by cognitively inspecting new input and output devices and verifying via a thought experiment that these I/O mechanisms could be represented in the taxonomy.

Part 2: *Physical Therapy*

In Chap. 4, "A Customizable Virtual Reality Framework for the Rehabilitation of Cognitive Functions," Gianluca Paravati, Valeria Maria Spataro, Fabrizio Lamberti, Andrea Sanna, and Claudio Giovanni Demartini present a virtual reality rehabilitation system, which they call VR2, for cognitive therapy along with a framework that was developed in collaboration with neuropsychology experts for adapting training scenarios, the main novelty offered by VR2 being a focus on system adaptation to the abilities of individuals or groups. Accordingly clinicians are provided with a set of tools for determining the number of stimuli present in rehabilitative scenarios and for testing and fine tuning parameters that personalize training sessions for individuals. Care is taken as well in the system to eliminate the effect of learning by generating randomly distributed stimuli and characteristics. This chapter not only describes the VR2 framework but it also presents a set of preliminary usability tests on a group of participants with cerebral lesions who varied widely in age and chronicity of the disorder. The training scenarios (named *library* and *supermarket*) focused on selective attention, i.e., the ability to focus on a stimulus or some relevant information in an environment containing competing stimuli and information. Patient acceptance of the system and its ability to produce cognitive improvement were examined, and results demonstrate VR2's usability and potential effectiveness. Included in this chapter is a short review of some state-of-the-art VR systems for rehabilitation involving motor and cognitive activities.

In Chap. 5, entitled "Technology for standing up and balance training in rehabilitation of people with neuromuscular disorders," Imre Cikajlo, Andrej Olenšek, Matjaž Zadravec, and Zlatko Matjaèiæ present a VR support balance training system that provides real-time balance feedback to patients undergoing dynamic balance training. Currently, a number of devices are available for dynamically maintaining balance (DMB); these devices are platforms that hold a patient upright while engaged in limited movement in all directions of the transversal plane. Newer systems are also being develop that use VR displays to provide visual correlates to the platform's movements. The authors of this chapter explore VR training with a DMB that has been modified with several additions: a haptic floor that translates in all directions of the horizontal plane and postural response assessment and progression from sit-to-stand with controlled active support. The results of several pilot studies using this system with both healthy and impaired participants are reported. These studies demonstrate not only the feasibility of using their system but also superior clinical results when compared to standard treatments. Some potential benefits of their VR balance training system that the authors point out include enabling the patient to train at home and a single physical therapists to supervise therapeutic procedures without an assistant and using only the DMB device. In addition, their system would allow the therapist to update difficulty levels and strategies that enhance adaptability to a broad range of environments.

In Chap. 6, entitled "Exergaming for Shoulder-Based Exercise and Rehabilitation," Alvaro Uribe-Quevedo and Bill Kapralos present two exergames that were developed specifically for shoulder-based exercise and rehabilitation. The first

exergame focuses on lateral and medial rotations, which are important movements for strength and functionality. The goal of the game is to paddle from an origin position in a lake to the finish line. Correct paddling results in swift navigation that allows collecting power bars to restore energy depletion caused by movement. The second exergame, Rapid Recovery makes use of the Spincore Helium 6 baton, a unique stand-alone fitness and rehabilitation device. The player's kayak paddling motions of the Helium 6 baton are captured at interactive rates (captured with the Microsoft Kinect), and mapped to movements in the game world. Rapid Recovery supports multiple players, allowing the opportunity for players to race each other. In the process of describing the two exergames, Uribe-Quevedo and Kapralos provide a detailed description of the upper limb (including the shoulder), to characterize ranges of motion, the body parts involved, and the exercises suitable to be implemented as exergames. This characterization provides information that serves as an initial step in determining the hardware and software development requirements. They also outline their experience in dynamic design, development, and preliminary user testing.

In Chap. 7, entitled "Development of an Occupational Health Care Exergaming Prototype Suite," Alvaro Uribe-Quevedo, Sergio Valdivia, Eliana Prada, Mauricio Navia, Camilo Rincon, Estefania Ramos, Saskia Ortiz, and Byron Perez leverage the engaging and motivational aspects of exergames to promote preventive exercise routines in the workplace. With the widespread use of computers and a variety of mobile devices in the workplace, computer-related health problems arising from prolonged and incorrect use of a computer (and/or mobile device) are increasing at a rapid pace. Preventive exercises can help reduce the risk of developing computer-related health problems and many employers encourage employees to perform various preventive exercises typically outlined in printed material and/or online. To overcome some of the issues associated with such an approach and most importantly, the lack of motivation amongst employees to start and maintain such exercise routines, the authors of this chapter outline an exergaming prototype suite comprised of four exergames developed specifically to address common work-related preventive exercises associated with the lower-limb, upper-limb, hands, and eyes. The exergames are designed as casual games intended to be played in short bursts, thereby allowing them to be incorporated into an employee's daily work routine.

In Chap. 8, "Game-Based Stroke Rehabilitation" by Mehran Kamkarhaghighi, Pejman Mirza-Babaei, and Khalil El-Khatib discuss and analyze advancements made in the areas of human computer interaction and games specifically for stroke-based rehabilitation. The chapter begins with an overview of stroke and its associated consequences and a discussion regarding the problems and drawbacks inherent in traditional stroke rehabilitation approaches. This is followed by an overview regarding the benefits of game-based stroke rehabilitation by linking the efforts and advancements made of the fields of human-computer interaction and games research to medical research. More specifically, a thorough discussion regarding increased patient motivation and engagement and lower access barriers to rehabilitation is provided. The chapter then proceeds to outline the requirements for

efficient game-based stroke rehabilitation which include the need to provide rehabilitation exercises for different parts of the body, monitor patient progress and provide feedback, provide diversity and flexibility to accommodate the wide range of stroke-based effects, and the need to allow for patient autonomy and the ability for patients to connect with other patients as part of their rehabilitation. A thorough literature review regarding game-based stroke rehabilitation is provided. The review provides historical context describing the most current efforts in the context of prior advancements. A summary of various games developed for stroke rehabilitation along with their target body part(s) and input devices employed, is provided in tabular form.

Part 3: *Touch and Wearables*
In Chap. 9, entitled "Multi-sensory environmental stimulation for users with multiple disabilities," Cristina Manresa-Yee, Ann Morrison, Joan Jordi Muntaner, and Maria Francesca Roig-Maimó present their multi-sensory environment which they call SINASense that combines a number of technologies, such as computer vision and hand recognition and vibratory and other tactile stimuli, with the aim of inducing the execution of particular body movements in people with multiple disabilities, including cognitive disabilities. After describing their system, the authors report a two-stage preliminary evaluation on users with cerebral palsy. Included in this chapter is a short review of the literature on interactive systems used in multi-sensory environments, defined as spaces that stimulate a person's senses in a way that does not require much high level cognitive processing, and vibrotactile interfaces for people with disabilities, esp. vision and cognitive disabilities.

In Chap. 10, entitled "Interactive Furniture: Bi-directional Inter-action with a Vibrotactile Wearable Vest in an Urban Space," Ann Morrison, Jack Leegaard, Cristina Manresa-Yee, Walther Jensen, and Hendrik Knoche investigate the experience of wearing a vibrotactile vest that interacts with a vibroacourtic wall, called *The Humming Wall,* located in a public urban park setting. The heart beats and breath rates of the vest wearers are publically and vibroacoustically displayed on The Humming Wall via an android API; whenever the wall is swiped or knocked upon, these stimuli are vibrotactically transmitted to the vest wearers. The authors situate their vest and huggable wall within both the huggable toy industry and the literature on health care wearables. One goal of the project is to reduce stress. Participants were asked questions about their experiences and a large amount of data was collected and analyzed regarding the interactions with the wall.

In Chap. 11, "The Acceptance, Challenges, and Future Applications of Wearable Technology and Virtual Reality to Support People with Autism Spectrum Disorders", authors Nigel Newbutt, Connie Sung, Hung Jen Kuo, and Michael. J Leahy present a review regarding the application of virtual reality technologies (VRTs), within a research context, to support those with Autism spectrum disorder. The chapter begins with a thorough review of the literature with an emphasis on the potentially useful application of VRTs to train and support those with an ASD with the development social skills, job skills, independent living skills (i.e., life skills).

The authors then outline the unique characteristics of VR that make it an effective intervention for those with autism. More specifically, the interactive nature of VR leads to an increase in user motivation, VR provided a safe and controlled environment allowing for repeated practice without real-world consequences when a mistake is made, VR provides the ability for immediate feedback and to track the users progress over time, a VR intervention can be customized to meet the unique needs of each user and this includes the manipulation of the presented stimuli and any distractors, and finally, a VR intervention allows for hierarchical learning where a scenario can differ slightly each time a user encounters it, forcing the user to think about different ways to solve the same problem. The paper then shifts focus to the use of head-mounted display- (HMD-) based VR for autism support given the gaining popularity of HMDs along with the potential benefits HMDs offer. Through a case study that involved the use of HMD-based VR amongst 29 participants with autism, the authors set out to examine the acceptance of wearing a HMD and more specifically, whether there are any adverse effects from the use of the HMD, and to gauge the 3D immersive experience and thus provide insight into whether HMD-based VR could be a potential intervention for the ASD population. The results of the study show promise regarding the use of HMD-based VR to support those with autism spectrum disorder, the study also revealed a number of potential concerns warranting further study.

Part 4: *Special Needs*
In Chap. 12, "Nursing Home Residents versus Researcher: Establishing Their Needs while Finding Your Way," Jon Ram Bruun-Pedersen describes problems encountered when designing exercise technology that uses virtual reality for nursing home residents. The author spent several years investigating, interviewing, and following the daily activities of residents in a local nursing home. The first part of this paper motivates the need for such technology. The author takes a detailed look at the elderly's reluctance to engage in physical exercise and offers a solution design that motivates this target group to engage in physical activities. Two studies are presented that examine the usefulness of the design solution that was derived from the author's careful investigations of the residents' needs. The second part of this chapter provides some insightful comments concerning the difficulties researchers encounter when doing research specific to this population.

Part 5: Ethics and Accessibility
In Chap. 13, "DigitalEthics: 'Ethical' considerations of post-research ICT impact", Anthony Brooks introduces a case study from the turn of the century conducted at the Centre for Advanced Visualization and Interactivity (CAVI) Aarhus University, Denmark. The subjects were four non-verbally capable children averaging five years of age diagnosed as suffering PMLD (profound and multiple learning disabilities). The children, attended by their personal professional care-providers, experienced unencumbered gesture control via the author created bespoke infrared sensor system (enabling movement of residual function in free space as controlling interface). CAVI's separate studio facilities were involved, i.e., the active 3D stereoscopic Virtual Reality Panorama studio, the Holobench studio, and the

Experimentarium. Multimodal stimuli in the studios were mapped from the author's sensor system enabling control by residual gesture within volumetric sensor spaces, which were scaled and otherwise tailored and fine-tuned according to differences of each child's ability. A specific focus presents how one of the children was deeply positively affected through interacting using his residual head motion to control a 'super-toy' (a VR model of a Star Wars fighter) in the Panorama studio and how this may have contributed to a post-research condition and outcome. A posited conclusion (from this speculated position) is how additional consideration for post-research impact in such instances of sensitivity need to be discussed and where necessary actioned such that where possible, funding and budgets address continued access aligned with training initiatives for facilitators to be empowered to optimize experiences and treatment.

In Chap. 14, "Accessibility: Definition, Labeling, and CVAA impact", Brooks, also the author of the previous chapter, elaborates on an act passed in USA regarding communication accessibility. The act updates a previous version to include encompassing game platforms and software. The contribution highlights the adoption of games with serious application in healthcare and beyond and points out some potential challenges and impact the act may have to this growing segment of support tool arsenal seen within various therapies. These are linked to the defined access challenges already in place for blind, deaf and cognitively impaired, and direct sources of information are introduced and shared in order to clarify issues involved. Such issues will align in the enforcing of the act, which many outside of the accessibility networks are not aware of. The chapter acts as an information messenger due to the dense data that has been sourced directly from selected main players such as AbleGamers Charity, PEGI (Pan European Game Information) age ratings and content labeling system), and other Special Interest Groups (SIGs). The contribution foresees challenges in enforcement of the CVAA aligned with the challenges of developers and industry to comply with requirements as expected and defined within game genres. A goal of the chapter is to promote discussions and awareness on accessibility issues and activities to realize increased inclusion that relates to technologies for inclusive wellbeing. An extended appendixes section adjoins this contribution by sharing the full CVAA and the full associated waiver granted to the games software industry, the latter presenting arguments associated to the innate challenges of compliance. The appendixes inclusion is considered an optimal means to inform the reader in printed form in one place the aligned materials.

1.3 Conclusion

These two volumes to date represent the referenced continuum starting with content sections as shared above, continued and advanced through the contributions in this volume where chapters are covering a wider gambit of topics to inform in and across fields relating to technologies of inclusive well-being.

However, as was asked in the first volume, what might a reader consider as they study this book (and the series)? Again, we believe Rizzo was eloquent in his preface to the first volume and insightful in his vision:

> We sometimes observe that great insights into the present turn up in the words of those who lived and died in a not-too-distant past. Such insights, derived from a relatively recent yet sufficiently disjointed past, can deliver a vision of the future that illuminates our present in surprising ways. This can be nicely illustrated in the words of the French author, poet, and aviator, Antoine de Saint-Exupery (1900–1944) with his comment, ''The machine does not isolate man from the great problems of nature but plunges him more deeply into them.'' While interpretations may vary, in one sentence from a writer who lived exclusively in the first half of the twentieth century, I see the exquisite juxtaposition of apprehension and engagement that always looms in our pursuit of technology solutions that address the problems of nature. This is not a bad thing. With whatever technology tools we have available, we plunge deeper into the nature of problems, and hopefully come close to where the solutions lie. I see this book in much the same fashion; a fascinating collection of visionary works by a diverse collection of scientists and practitioners who implicitly acknowledge the same struggle. The many ideas presented in these pages for using digital technology to help change the course of challenged lives in ways unthinkable in just the last century is bold and provocative. And to do this requires a team of scientists, artists, programmers, clinicians, users, among others, who are willing to plunge deeply into the struggle, rather than to use technology to become isolated from the reality of the challenges that we aim to address. The authors in this book have successfully done this and these writings will play a significant part in further illuminating the bright future in this area.

In closing this opening statement, the editors reflect on this growing field and the advancements and impact of increased digital media adoption across associated practices. Today's pioneers and ambassadors, who are pushing the boundaries and limits previously conceived in this wide-ranging field, realize it is not solely about technology, importantly, it is increasingly about the thinking behind the technic that targets human performance and the conviction to put words into practice in such a way to impact society and benefit others. Enjoy the read, enjoy the journey!

Reference

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Part I
Literature Reviews and Taxonomies

Chapter 2
An Overview of Serious Game Engines and Frameworks

Brent Cowan and Bill Kapralos

Abstract Despite the growing popularity and widespread use of serious games, the development of effective serious games is difficult, requiring an appropriate balance between game design and instructional design. Although there are fundamental differences between games developed purely for entertainment compared to those developed for "serious" purposes, there are currently no standard development tools specifically intended for serious game design and development available that encourage developers to follow a set of best practices. Rather, developers of serious games often rely on existing game engines and frameworks that are specific to entertainment-based game development. Given the availability of a large number of game engines and frameworks, deciding on which one to use to develop a serious game may be difficult, yet the choice of engine or framework can play a significant role in the development process. In this paper we present the results of a literature review that examined the frameworks and game engines that are used to develop serious games. We provide a list of the most commonly used frameworks and game engines and summarize their features. Knowledge of the frameworks and game engines that are most popular and details regarding why they are popular may prove to be useful to serious games developers seeking such tools. The chapter ends with a brief discussion regarding a framework that is currently being developed specifically for the development of serious games. Through consultation with the potential users of the framework (serious games developers), the framework aims to strike a balance between ease of use and functionality, while providing the user with the necessary options and tools to ideally develop effective serious games.

Keywords Serious gaming · Virtual simulation · Game engine · Game development · Framework · Review

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2.1 Introduction

The idea of using games for purposes other than entertainment was first formulated in a book titled 'Serious Games' by Clark C. Abt in 1975. Abt introduces the concept of serious games and defines them by stating: "We are concerned with serious games in the sense that these games have an explicit and carefully thought-out educational purpose and are not intended to be played primarily for amusement" [1]. The examples discussed by Abt were limited to table-top ("board") games as video games were still in their infancy in 1975. In 2002, motivated by Clark Abt's book 'Serious Games', David Rejeski from the Woodrow Wilson Center for Scholars added the term serious games to a report Ben Sawyer prepared titled "Improving Public Policy through Game-based Learning and Simulation" [47]. The expression "serious game" may be seen as a contradiction, or a tautology [7]. More specifically, if games are fun, how can they also be serious? It could even be argued that games have an evolutionary background as instruments for survival training [7]. Although no particularly clear definition of the term is currently available, "serious games" usually refer to games that are used for training, advertising, simulation, or education, and are designed to run on personal computers or video game consoles [55]. Serious games have also been referred to as "games that do not have entertainment, enjoyment, or fun as their primary purpose" [34]. A serious game can more formally be defined as an interactive computer application, with or without a significant hardware component that (i) has a challenging goal, (ii) is fun to play and/or engaging, (iii) incorporates some concept of scoring, and (iv) imparts to the user a skill, knowledge, or attitude that can be applied to the real world [5]. The terms "serious game" and "educational game" are often used interchangeably. However, the primary purpose of a serious game is not necessarily educational. For example, the America's Army series of games serve as a recruitment tool designed to persuade young people to consider a career in the U. S. military [59]. Educational games are typically viewed as a subset of serious games, and are mainly developed for use within kindergarten to grade twelve (K-12) education [42]. Education generally refers to the acquisition of knowledge, while training refers to the acquisition of both skills and knowledge. Educational games generally focus on the acquisition of knowledge while using entertainment as a motivator.

Serious games "leverage the power of computer games to captivate and engage players for a specific purpose such as to develop new knowledge or skills" [13] and greater engagement within an educational setting has been linked to higher academic achievement [50]. In addition to promoting learning via interaction, there are various other benefits to serious games. More specifically, they allow users to experience situations that are difficult (even impossible) to achieve in reality due to a number of factors including cost, time, safety, and ethical concerns [54]. Serious games may also support the development of various skills including analytical and spatial, strategic, recollection, and psychomotor skills, as well as visual selective attention [36]. Further benefits of serious games may include improved

self-monitoring, problem recognition and solving, improved short- and long-term memory, and increased social skills [36]. Serious games are being applied within a wide range of applications including, medical/surgical skills development [3], military strategy training [43], and interpersonal skills development [8]. Given the ubiquity of video game use across a large demographic (i.e., males, females, youth, and the elderly), and their ability to engage and motivate learners, the popularity of serious games has seen a recent surge across many areas of education and training.

Despite the growing popularity of serious games and the benefits they afford, the development of effective serious games is a difficult and time consuming process, requiring an appropriate balance between game design and instructional design. It has been suggested that a lack of proper instructional design will lead to ineffective serious games or "instructional games" [4, 26]. Further complicating matters, there are currently no standard development tools available that emphasize, and encourage developers of serious games to follow best practices. Many serious game developers are using tools that were developed for the creation of commercial entertainment games instead of tools designed specifically for education and training. Serious games are often developed by developers with limited knowledge regarding a game's educational content and possess limited, if any knowledge of instructional design.

In order to understand how serious games are currently being developed, we begin by examining the development tools used to create them. Here, we present the results of two literature reviews that were conducted across three databases. The first survey compiled a list of development tools that were frequently mentioned in academic writing. A search was performed for each framework using three separate search terms. By measuring the number of search results for each framework in relation to each search term, we determined which development tool or framework is the "most discussed academically". In addition to measuring the notoriety of each framework/engine, separating the results by search term allows us to examine the context in which the framework/engine was frequently discussed. The second survey was conducted to determine which tools were utilized most often in the creation of a serious game. By knowing which tools are popular among the developers of serious games, we are able to investigate the features that are most important to developers. The toolset utilized to create a game may also provide insight regarding the size of the team, their skill level, and the project's budget.

2.1.1 Paper Organization

The remainder of this paper is organized as follows. Section 2.2 provides background information, and more specifically, an overview of existing frameworks and game engines. The results of a literature review that examined the tools (game engines and frameworks), used to develop serious games are also presented. This review led to a compiled list of the frameworks and game engines that are the most popular among serious games developers. A discussion of the survey results and

concluding remarks are provided in Sect. 2.3. This includes a summary of the most popular game engines and frameworks along with common features that are important to developers of serious games in addition to a description of our ongoing work that is seeing the development of a serious game framework for medical education. This framework is intended to bridge the gap between the specific needs of serious game developers and the development tools they currently have available to them.

2.2 Game Engines and Frameworks

With respect to entertainment-based video games, early video games such as Pong were designed to run on hardware that was not well suited for video game development. With little in the way of processing power or memory to work with, games were typically written completely from scratch in assembly language (a low-level language). The close link between the game "code" and the hardware prevented the code from being re-used [6]. As hardware capabilities improved, higher level languages such as C/C++ and Java gradually replaced assembly language for game programming, leading to greater code re-use. Over time, many game companies accumulated a library of well-tested reusable code. To further reduce production time, simplified Application Programming Interfaces (APIs) and external tools such as level editors were developed. id software began licensing their Quake engine to other companies as an additional source of revenue in 1996 [31]. Other companies such as Epic Games soon began licensing their game engines (Unreal) too. There are now hundreds of commercial game engines competing for licensees. Modern game engines provide advanced rendering technologies, simple tools for content creation, allow game developers to reuse code, and decrease development time and costs [31]. Sherrod [49] defines a game engine as "a framework comprised of a collection of different tools, utilities, and interfaces that hide the low-level details of the various tasks that make up a video game". The terms "game engine" and "framework" are often used interchangeably. For the purpose of this paper, the term game engine refers to the functionality and features that become part of the completed game. A framework includes a game engine in addition to tools and interfaces that simplify the process of game development (this is depicted graphically in Fig. 2.1).

Listed below are the main features provided by most modern game engines. The code responsible for providing this functionality becomes a part of the finished game.

- **Scripting**: Simple code that can be written to control game objects and events.
- **Rendering**: The speed and accuracy by which a three-dimensional (3D) scene is generated, as well as the visual effects provided.
- **Animation**: The movement and deformation of objects, such as characters.

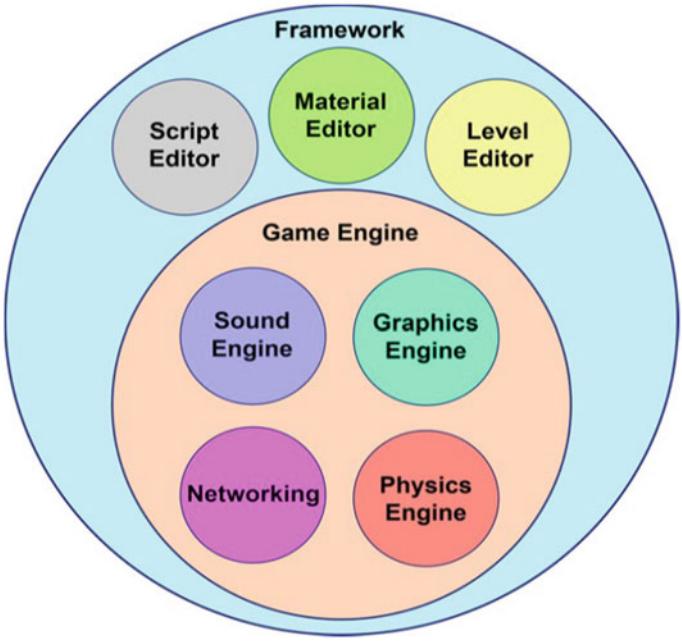

Fig. 2.1 The relationship between game framework, game engine, and their constituent components

- **Artificial Intelligence**: Steering behaviors, such as pursuing, dodging, and fleeing are combined with path finding.
- **Physics**: Objects respond accurately to applied forces or pressures (e.g., when colliding).
- **Audio**: Spatial rendering of audio allows sounds to have a location within the environment. Digital Signal Processing (DSP) is used to add variation as well as environmental cues such as reverberation.
- **Networking**: Allows players to interact with other players within the game by sharing data through a network.

Game creation frameworks generally provide a Graphical User Interface (GUI) which often ties together several editors. Listed below are some of the editing tools commonly included with game creation frameworks:

- **Level Editor**: Also known as a "world editor", this tool aids in the creation of two-dimensional (2D) or three-dimensional (3D) environments (game levels, maps, etc.).
- **Script Editor**: Scripts can be attached to objects selected in the level editor to customize their behavior.