

On Edge Human Action Recognition Using Radar-Based Sensing and Deep Learning

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and Maurizio Valle , Senior Member, IEEE

Abstract—In this article, we propose a radar-based human action recognition system, capable of recognizing actions in real time. Range-Doppler maps extracted from a low-cost frequency-modulated continuous wave (FMCW) radar are fed into a deep neural network. The system is deployed on an edge device. The results show that the system can recognize five human actions with an accuracy of 93.2% and an inference time of 2.95 s. Raising an alarm when a harmful action happens is a crucial feature in an indoor safety application. Thus, the performance during the binary classification, i.e., fall vs nonfall actions, is also assessed, achieving an accuracy of 96.8% with a false-negative rate of 4%. To find the best tradeoff between accuracy and computational cost, the energy precision ratio of the system deployed on the edge is measured. The system achieves a 1.04 energy precision ratio value, where an ideal ratio would be close to zero.

Index Terms—Action recognition, deep neural networks (DNNs), edge deployment, frequency-modulated continuous wave (FMCW) radar.

I. INTRODUCTION

FALLS are a major public health concern and the main cause of accidental death in the senior population worldwide. Timely and accurate detection permits immediate assistance after a fall and, thereby, reduces complications of fall risk [1]. Edge-based approaches are essential to support time-dependent healthcare applications [2].

Due to the advantages of portability, low cost, and availability, wearable devices are regarded as one of the key types of sensors

for fall detection and have been widely studied [3], [4], [5], [6]. The main drawback of these systems is the battery life which can limit the usability of the wearable devices. The second drawback is that the monitored subjects must always wear them, causing obvious discomfort, especially for the elderly.

Vision-based fall detection is another prominent method. Extensive effort in this direction has been demonstrated, showing promising results [7], [8], [9]. Although cameras are not as portable as wearable devices, they offer other advantages that deem them as decent options depending on the scenario: most static RGB cameras are not intrusive and wired, hence there is no need to worry about battery limitations. One major drawback of vision-based detection is the potential violation of privacy due to the levels of detail that cameras can capture, such as personal information, appearance, and visuals of the living environment. The second drawback is the high sensibility to clutters and environmental conditions (e.g., smoke, light, etc.). In addition, a vision-based approach could introduce issues related to color bias [10].

Ambient sensors (e.g., ultrasonic, WiFi antennas, radars, etc.) provide another nonintrusive means of fall detection. Ambient sensing is drawing more attention which can be attributed to being device-free for users and can solve the problem of people's privacy and color bias. Ultrasonic sensor network systems are one of the solutions for fall detection [11]. One drawback is that the waves are affected by environmental factors, such as humidity and smoke. These would affect the accuracy of the measurement. In [12], a fall detection approach uses WiFi signals, showing promising results in detecting falls. This approach is susceptible to security threats and has a limited range of efficiency.

Radars have become popular in recent years, proving to be an effective sensor to recognize human actions in cluttered environments [13]. In [14] and [15], the human action recognition is performed by a machine learning (ML) algorithm trained on hand-crafted features extracted from the radar signals. The main drawback is the time and effort required for the processing of the data and the feature extraction operation. Some other works propose deep neural networks (DNNs) to automatically extract features for human action recognition and fall detection. In [16], stack autoencoders (AEs) are used to automatically extract the features from the gray-scale spectrogram and to classify four activities including the fall. In [17], the authors combine convolutional neural networks (CNNs) and AEs to classify 12 actions based on micro-Doppler signatures. In [18], two DNNs

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All the codes and data used in the work are available on GitHub: <https://github.com/cosmiclabunige/ActionRecognition>.

Color versions of one or more figures in this article are available at <https://doi.org/10.1109/TII.2023.3316164>.

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Figueiredo, Paula Cristina
Nunes,Tomé, Eduardo Luís de Campos
Soares,Rouco, José Carlos Dias

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Blade runner H. W. Jeter,19?? **Blade runner 2** K. W. Jeter,1996 **International Encyclopedia of Human Geography** ,2019-11-29 International Encyclopedia of Human Geography Second Edition Fourteen Volume Set embraces diversity by design and captures the ways in which humans share places and view differences based on gender race nationality location and other factors in other words the things that make people and places different Questions of for example politics economics race relations and migration are introduced and discussed through a geographical lens This updated edition will assist readers in their research by providing factual information historical perspectives theoretical approaches reviews of literature and provocative topical discussions that will stimulate creative thinking Presents the most up to date and comprehensive coverage on the topic of human geography Contains extensive scope and depth of coverage Emphasizes how geographers interact with understand and contribute to problem solving in the contemporary world Places an emphasis on how geography is relevant in a social and interdisciplinary context **Dental Image Processing for Human Identification** Deven N. Trivedi,Nimit D. Shah,Ashish M. Kothari,Rohit M. Thanki,2019-01-28 This book presents an approach to postmortem human identification using dental image processing based on dental features and characteristics and provides information on various identification systems based on dental features using image processing operations The book also provides information on a novel human identification approach that uses Infinite Symmetric Exponential Filter ISEF based edge detection and contouring algorithms Provides complete details on dental imaging Discusses the important features of a human identification approach and presents a brief review on DICOM standard for dental imaging Presents human identification approach based on dental features **Human Interface and the Management of Information** Hirohiko Mori,Yumi Asahi,2023-07-08 This two volume set LNCS 14015 14016 constitutes the thoroughly refereed proceedings of the thematic area Human Interface and the Management of Information HIMI 2023 which was held as part of HCI International 2023 which took place in Copenhagen Denmark during July 23 28 2023 A total of 1578 papers and 396 posters have been accepted for publication in the HCII 2023 proceedings from a total of 7472 submissions The papers included in the HCII HIMI volume set were organized in topical sections as follows Part I Information design and user experience data visualization and big data multimodal interaction interacting with AI and intelligent systems Part II Service design knowledge in eLearning and eEducation supporting work and collaboration **To Kill Cow Means To End Human Civilization** Dr. Sahadeva Das,2018-01-01 To Kill Cow Means To End Human Civilization Today we are treating other life forms just like inert objects as if they are devoid of any feelings whatsoever We are showing unprecedented cruelty and callousness towards the dumb creation of God with whom we share this planet Cruelty has been industrialized barbarism has been institutionalized Today the mistreatment of animals is phenomenal unprecedented in human history The unspeakable treatment meted out to poor animals before they become our dinner will never go unpunished by the stringent laws of nature *SEC Docket* United

States. Securities and Exchange Commission,1987 **American Medicine** ,1921 Intelligent Human Systems Integration Waldemar Karwowski,Tareq Ahram,2017-12-30 This book reports on research on innovative human systems integration and human machine interaction with an emphasis on artificial intelligence and automation as well as computational modeling and simulation It covers a wide range of applications in the area of design construction and operation of products systems and services including lifecycle development and human technology interaction The book describes advanced methodologies and tools for evaluating and improving interface usability new models as well as case studies and best practices in virtual augmented and mixed reality systems with a special focus on dynamic environments It also discusses different factors concerning the human hardware and artificial intelligence software Based on the proceedings of the 1st International Conference on Intelligent Human Systems Integration IHSI 2018 held on January 7 9 2018 in Dubai United Arab Emirates the book also examines the forces that are currently shaping the nature of computing and cognitive systems such as the need for decreasing hardware costs the importance of infusing intelligence and automation and the related trend toward hardware miniaturization and power reduction the necessity for a better assimilation of computation in the environment and the social concerns regarding access to computers and systems for people with special needs It offers a timely survey and a practice oriented reference guide to policy and decision makers human factors engineers systems developers and users alike **Human Rights Of, By, and For the People** Keri Iyall Smith,Louis Edgar Esparza,Judith Blau,2017-02-03 Together the US Constitution and the Bill of Rights comprise the constitutional foundation of the United States These the oldest governing documents still in use in the world urgently need an update just as the constitutions of other countries have been updated and revised Human Rights Of By and For the People brings together lawyers and sociologists to show how globalization and climate change offer an opportunity to revisit the founding documents Each proposes specific changes that would more closely align US law with international law The chapters also illustrate how constitutions are embedded in society and shaped by culture The constitution itself sets up contentious relationships among the three branches of government and between the federal government and each state government while the Bill of Rights and subsequent amendments begrudgingly recognize the civil and political rights of citizens These rights are described by legal scholars as negative rights specifically as freedoms from infringements rather than as positive rights that affirm personhood and human dignity The contributors to this volume offer positive rights instead The Universal Declaration of Human Rights UDHR written in the middle of the last century inspires these updates Nearly every other constitution in the world has adopted language from the UDHR The contributors use intersectionality critical race theory and contemporary critiques of runaway economic inequality to ground their interventions in sociological argument The Anatomy of the human peritoneum and abdominal cavity George Sumner Huntington,1903 Human Anatomy ,1914 Bionic Human Aurora Amoris,2025-01-01 The integration of advanced technology with human biology is no longer a concept of science

fiction it s becoming a reality This book delves into the transformative world of bionic humans exploring the cutting edge developments that are reshaping what it means to be human From the creation of artificial limbs and neural prosthetics to the potential of genetic modification this work covers the scientific principles behind bionic technologies and their profound implications on human life It investigates how technology can interface with the brain enabling control over artificial organs and movement through thought The future possibilities for human enhancement are vast offering new solutions to aging disabilities and even the very nature of human existence Beyond the science the book explores the ethical and societal challenges posed by these advancements What will be the legal and social status of bionic humans How will society respond to the widespread acceptance of artificial enhancements The implications for human identity equality and the moral questions raised by these technologies are examined in depth This exploration also considers the impact of these technologies on our health and longevity pushing the boundaries of human life expectancy With the potential to redefine human capabilities and longevity this work paints a picture of a future where the human body and technology are inseparably intertwined offering a vision of evolution that is both thrilling and thought provoking

Handbook of Research on Challenges for Human Resource Management in the COVID-19 Era Figueiredo, Paula Cristina Nunes,Tomé, Eduardo Luís de Campos Soares,Rouco, José Carlos Dias,2022-06-10 The importance of people in organizations has been growing in the organizational environment over the last decades Digital transformation artificial intelligence and sustainability have already reinforced the role of people as a differentiating element for the success and survival of organizations These phenomena alone are already challenging for people There is a consensus that the world of work as we knew before the pandemic will not return Human resource management HRM practices must prepare organizations for the future of work The Handbook of Research on Challenges for Human Resource Management in the COVID 19 Era analyzes state of the art HRM in a digital transformation context and investigates the factors that promote more learning and development dynamics in organizational contexts It also evaluates the impact of HRM policies on individuals organizations and societies Covering topics such as corporate social responsibility job satisfaction and electronic performance monitoring this major reference work is a crucial resource for leaders from public and private companies human resource professionals specialists students and educators of higher education researchers and academicians

Human Capital Management and Competitive Advantage in Tourism Silic, Mario,Luthia, Mahesh,Ahmad, Faizan,Chakraborty, Partha Pratim,2025-06-12 Human capital management HCM plays a pivotal role in shaping competitive advantage within the tourism industry where service quality customer experience and innovation are key differentiators As tourism becomes competitive and globalized the ability to attract develop and retain skilled workers is essential for businesses Effective HCM strategies like investing in employee training fostering a positive organizational culture and leveraging technology for talent management can empower organizations to enhance service delivery improve operational efficiency and adapt to changing market demands In an

industry where human interactions often define success creating a workforce that is not only skilled but also motivated and customer centric can be the difference between thriving and surviving The strategic management of human capital has become an integral part of achieving long term sustainability and growth in the tourism sector Human Capital Management and Competitive Advantage in Tourism explores the role of sustainable human capital management in developing a competitive advantage for the tourism sector It presents frameworks tools and approaches by integrating theory and practice to support human development in the sector through new technology and contemporary human development This book covers topics such as human capital talent management and digital technology and is a useful resource for business owners economists engineers academicians researchers and data scientists

Human Rights Watch World Report 2000 Human Rights Watch (Organization), Human Rights Watch Staff, 1999 Human rights watch world report 2001 events of 2000

The New HR Analytics Jac FITZ-ENZ, 2010-05-12 Using Fitz enz s proprietary analytic model you will be equipped to measure and evaluate past and current returns and apply the information to make predictions about the future value of human capital investments In his landmark book The ROI of Human Capital Jac Fitz enz presented a system of powerful metrics for quantifying the contributions of individual employees to a company s bottom line Now in The New HR Analytics he reveals how human resources professionals can apply this expense based knowledge to make the most strategic staffing decisions for their companies You ll learn how to evaluate and prioritize the skills needed to sustain performance build an agile workforce through flexible Capability Planning determine how the organization can stimulate and reward behaviors that matter apply a proven succession planning strategy that leverages employee engagement and drives top line revenue growth and recognize risks and formulate responses that avoid surprises Brimming with real world examples and input from thirty top HR practitioners and thought leaders as well as exclusive analytical tools The New HR Analytics ushers in a new era in human resources and human capital management

Strengthening U.S. Air Force Human Capital Management National Academies of Sciences, Engineering, and Medicine, Division of Behavioral and Social Sciences and Education, Board on Human-Systems Integration, Committee on Strengthening U.S. Air Force Human Capital Management, 2021-03-02 The USAir Force human capital management HCM system is not easily defined or mapped It affects virtually every part of the Air Force because workforce policies procedures and processes impact all offices and organizations that include Airmen and responsibilities and relationships change regularly To ensure the readiness of Airmen to fulfill the mission of the Air Force strategic approaches are developed and issued through guidance and actions of the Office of the Deputy Chief of Staff for Manpower Personnel and Services and the Office of the Assistant Secretary of the Air Force for Manpower and Reserve Affairs Strengthening US Air Force Human Capital Management assesses and strengthens the various U S Air Force initiatives and programs working to improve person job match and human capital management in coordinated support of optimal mission capability This report considers the opportunities and challenges associated with related interests and needs

across the USAF HCM system as a whole and makes recommendations to inform improvements to USAF personnel selection and classification and other critical system components across career trajectories Strengthening US Air Force Human Capital Management offers the Air Force a strategic approach across a connected HCM system to develop 21st century human capital capabilities essential for the success of 21st century Airmen **Space, Time and the Limits of Human**

Understanding Shyam Wuppuluri, Giancarlo Ghirardi, 2016-12-01 In this compendium of essays some of the world's leading thinkers discuss their conceptions of space and time as viewed through the lens of their own discipline With an epilogue on the limits of human understanding this volume hosts contributions from six or more diverse fields It presumes only rudimentary background knowledge on the part of the reader Time and again through the prism of intellect humans have tried to diffract reality into various distinct yet seamless atomic yet holistic independent yet interrelated disciplines and have attempted to study it contextually Philosophers debate the paradoxes or engage in meditations dialogues and reflections on the content and nature of space and time Physicists too have been trying to mold space and time to fit their notions concerning micro and macro worlds Mathematicians focus on the abstract aspects of space time and measurement While cognitive scientists ponder over the perceptual and experiential facets of our consciousness of space and time computer scientists theoretically and practically try to optimize the space time complexities in storing and retrieving data information The list is never ending Linguists logicians artists evolutionary biologists geographers etc all are trying to weave a web of understanding around the same duo However our endeavour into a world of such endless imagination is restrained by intellectual dilemmas such as Can humans comprehend everything Are there any limits Can finite thought fathom infinity We have sought far and wide among the best minds to furnish articles that provide an overview of the above topics We hope that through this journey a symphony of patterns and tapestry of intuitions will emerge providing the reader with insights into the questions What is Space What is Time Chapter 15 of this book is available open access under a CC BY 4.0 license

Innovative Approaches for International Competitiveness Through Human Resource Management

Pawirosumarto, Suharno, 2025-05-09 In an era of global interconnectedness and competition organizations utilize innovative approaches to human resource management HRM to remain competitive Effective HRM strategies include cross cultural management global workforce optimization and the integration of technology in employee development By embracing diversity fostering a culture of continuous learning and leveraging data driven insights businesses can cultivate a workforce that is adaptable to the needs of global markets Strategic HRM practices such as flexible work models employee empowerment and leadership development programs empower organizations to respond to market shifts quickly and maintain a competitive edge across borders In this context innovative HRM approaches are a tool for operational efficiency and long term international success Innovative Approaches for International Competitiveness Through Human Resource Management explores contemporary challenges and strategies in human resource management HRM within a global context

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