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Nurturing well-being: How African researchers are using artificial intelligence and machine learning to address health challenges

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Acknowledgment

The project team would like to express heartfelt gratitude to the dedicated researchers who have played a pivotal role in shaping and enriching the synthesis report under the AI4D Africa Scholarship project. Your commitment to excellence, rigorous inquiry, and collaborative spirit have significantly contributed to the depth and breadth of our understanding of AI in the African context. This synthesis report stands as a testament to your invaluable contributions, and we extend our sincere appreciation for your hard work and expertise.

Preface

The African Centre for Technology Studies (ACTS) is the lead implementing agency for the Artificial Intelligence for Development in Africa (AI4D) Scholarship project that aims to foster and nurture talent in responsible Artificial Intelligence (AI) and Machine Learning (ML) in African public universities. The 3-year project, funded by the International Development Research Centre (IDRC) and the Swedish International Development Cooperation Agency (SIDA), aims to meet the growing demand for research and development in responsible Artificial Intelligence (AI) and Machine Learning (ML) in the continent. ACTS is implementing the AI4D Africa scholarship project in partnership with Kwame Nkrumah University of Science & Technology in Ghana; University of Linkoping, Sweden and Université Cheikh Anta Diop de Dakar, Senegal. Other partners include the Regents of the University of California, United States; Human Sciences Research Council and Institute for Humanities in Africa based in South Africa; and the University of Eduardo Mondlane, Mozambique.

Specifically, the project is supporting selected scholars to undertake and successfully complete PhD research in AI and ML in African universities; and early career academics (ECA) to strengthen their research and development capacities in the two areas. Special consideration is given to research projects on responsible AI innovation for sustainable development, gender equity, and equitable regional distribution in low-income countries. This initiative is built on the premise that whereas majority of doctoral graduates expect to secure jobs in academic and research, a postdoctoral period is desirable to develop fully-fledged, independent, and competent researchers. Also, there are very few universities in Africa that currently offer MSc and PhD programs in AI and ML. The bulk of the departments, however, do offer MSc and PhD in ICT related courses with some potential to supervise PhD in AI and ML. Apart from supporting research capacities of selected scholars, the programme will enhance the capacities of existing ICT departments to offer MSc and PhD in AI and ML by supporting them with research tools and related infrastructure for AI and ML. This will not only facilitate research activities of Early Career Academics (ECA) but will also be made available to other postgraduate and final year undergraduate students within the departments.

The program design has also lined up a series of complementary activities that will help enhance research capacities of the scholars which include short-courses, PhD Academy, quarterly seminars, annual workshops, mentorship, regional conferences and online training. After three years, it is expected that there will be a critical mass of scholars to enhance research and development in AI and ML related fields while public universities in sub-Saharan Africa will have developed their capacities to provide postgraduate training in AI and Machine Learning. In addition, there will be adequate access to knowledge by researchers and practitioners and enhanced networking opportunities of the AI and ML scholars. The programme is also expected to generate substantial evidence for policy making on AI and ML related issues enhanced in Sub-Saharan Africa.

We extend our gratitude to the scholars whose dedication and ingenuity have contributed to this report. May their work inspire further inquiry, collaboration and advancements that enhance the health and well-being of communities across Africa.

I. AI4D Africa research projects in health

The AI4D Africa Scholarship project has been a catalyst for change, providing a unique platform for scholars to delve into the expansive world of AI and ML. Through a series of research projects, the scholars have explored diverse applications, from healthcare and agriculture to education and environmental sustainability. This synthesis report aims to distill the collective wisdom and insights gained through these endeavors. The project has ushered in a new era of exploration, where scholars have harnessed the power of AI and ML to address pressing health challenges across the African continent. The projects are not just focusing on the technical intricacies of algorithms but, more importantly, focus on real world challenges that affect populations in Africa.

AI4D Africa scholars, hailing from diverse backgrounds and regions of Africa, have undertaken projects that address health disparities, accessibility issues, and the complex interplay challenges facing healthcare on the continent. From predictive models for disease outbreaks to innovative applications enhancing healthcare delivery, this report encapsulates the breadth and depth of their work. Beyond the algorithms and data sets, these projects embody a commitment to inclusivity, equity, and the pursuit of better health outcomes for all.

This report is an invitation to engage with the evolving landscape of AI in health, understanding its potential to reshape the healthcare narrative in Africa. From innovative telemedicine solutions to predictive models for disease prevention, each research project sheds light on the progress, resilience, and a collective aspiration for healthier futures. The research projects highlight ways in which AI and ML have been harnessed to bridge gaps in healthcare accessibility, enhance diagnostic capabilities, and contribute to the overall well-being of communities.

In each project, scholars have grappled with real-world challenges, striving not only for technical excellence but also for solutions that resonate with the diverse and dynamic healthcare landscape of Africa.

Therefore, this synthesis report is more than a culmination of projects; it is an open invitation to all stakeholders -researchers, policymakers, practitioners, and communities - to join hands in the ongoing conversation about the role of AI and ML in shaping a healthier future for Africa. It is a reflection on challenges to be overcome, and a roadmap for continued collaboration and exploration on how we can use AI and ML to address health challenges in Africa.

II. Socio-economic significance of AI4D Africa Research projects

In this section, we focus on the profound socio-economic significance of seven pioneering projects that blend cutting-edge technology with a commitment to addressing real-world health challenges.

Early detection of chronic lung diseases

Developing a predictive model and decision support system for Chronic Obstructive Pulmonary Disease (COPD) or simply chronic lung disease patients through wearable pulse oximeters holds the promise of transforming COPD care. By leveraging real-time data, this technology could enable early detection of exacerbations, leading to personalized and timely interventions. The implementation of predictive models allows for early identification of potential exacerbations in COPD patients. Timely intervention based on these predictions can mitigate the severity of symptoms, potentially reducing hospitalizations and emergency room visits. This, in turn, translates to substantial cost savings within healthcare systems, as resources are directed more efficiently. Also, the data generated by wearable devices can inform evidence-based healthcare policies, guiding policymakers in resource allocation and strategic planning

Surveillance of dengue fever and Chikungunya

The implementation of an agent-based model for dengue and Chikungunya surveillance in Sub-Saharan Africa aims to revolutionize disease prevention and control. By providing early detection and facilitating targeted interventions, this model has the potential to significantly reduce the burden on healthcare systems, improve community health, and contribute to overall socioeconomic well-being by preventing outbreaks and minimizing the economic impact of these diseases. The potential socioeconomic significance of this research project lies in its capacity to improve disease surveillance, enhance early intervention, optimize resource allocation, and ultimately contribute to the economic well-being of communities in Sub-Saharan Africa. By addressing the challenges posed by Dengue and Chikungunya through advanced modeling, this research has the potential to positively impact public health outcomes and contribute to the broader global effort in disease prevention and control.

Early retinal disease detection

Introducing an ensemble convolutional neural network for multiclass, multi-label retinal disease detection has profound implications for health. This technology could revolutionize the diagnosis of retinal diseases thus reducing healthcare costs associated with advanced treatments. The socioeconomic impact extends to improved productivity and quality of life for individuals, with potential benefits for both healthcare providers and patients. Implementation of a sophisticated neural network for disease detection can streamline healthcare processes and reduce the burden on healthcare systems. Automated screening tools can assist healthcare professionals in efficiently managing

large volumes of retinal images, allowing for quicker and more accurate diagnoses. This, in turn, can contribute to cost savings within healthcare systems, optimizing resource allocation for improved patient care. Furthermore, the integration of cutting-edge technology in healthcare, such as ensemble convolutional neural networks, positions the research project at the forefront of innovation. Successful implementation of this technology may lead to advancements in the broader field of medical imaging and artificial intelligence applications in healthcare, potentially fostering economic growth and job creation in related industries.

Improving security for e-health in developing countries

Focusing on Internet of Things (IoT) security for e-health in developing countries addresses a critical aspect of digital healthcare. By enhancing data privacy and trust, this research could promote wider adoption of digital healthcare services. The resulting impact includes improved access to healthcare, particularly in underserved areas, and the potential for more efficient, secure, and equitable healthcare delivery. Enhancing IoT security in e-health systems is crucial for safeguarding sensitive healthcare data. In developing countries, where healthcare systems may be more vulnerable to cyber threats, a robust security framework can protect patient information, ensuring privacy and confidentiality. This, in turn, fosters trust in e-health platforms, encouraging greater adoption and utilization of digital health services. As these technologies become more secure, healthcare providers can confidently implement remote healthcare solutions, expanding access to medical services in underserved areas. This has the potential to reduce the burden on already strained healthcare infrastructure in developing regions.

Faster retrieval of health records

The development of a speech improvement framework, employing long short-term memory neural networks and dynamic time warping, for health records retrieval at Kenyatta National Hospital represents a significant advancement in healthcare efficiency. This technology could streamline processes, reduce administrative burdens, and enhance patient care by providing faster access to relevant medical information, thereby positively impacting both healthcare professionals and patients. Implementation of a speech improvement framework can significantly expedite the health records retrieval process. Healthcare practitioners can use spoken language to swiftly access patient information. This has the potential to reduce administrative burdens, enhance workflow efficiency, and ultimately contribute to improved patient care. Healthcare providers can access critical patient data rapidly, facilitating quicker diagnosis and treatment planning. This, in turn, can positively impact patient outcomes and contribute to overall healthcare quality.

Faster ideentification, compilation and reporting of causes of death

Implementing a hybrid approach in verbal autopsy cause of death determination offers a transformative path for public health planning. By enhancing the accuracy of cause-of-death determinations, this research could inform data-informed policies,

resource allocation, and targeted interventions. These study, which has since been completed, has now influenced how the government of Tanzania collect, compiles and report mortality statistics. Previously, the Ministry of Health in Tanzania compiled verbal autopsy and medically certified reports separately. But now, based on the model developed from this study, the Ministry of Health in Tanzania is integrating both sets of data – medically certificated reports and verbal autopsy generated by the model - into one national mortality statistics report.

Automatic generation of biomedical image captions

The automatic generation of biomedical image captions has the potential to revolutionize medical communication and collaboration. This technology facilitates improved understanding among healthcare professionals and enhances education and training. Automatic generation of captions for biomedical images can significantly enhance medical education and training. Health professionals, researchers, and students can benefit from detailed and contextually relevant descriptions of images, fostering a deeper understanding of complex medical conditions, diagnostic procedures, and treatment methodologies. Healthcare practitioners can access quick, concise, and standardized information about patients' diagnostic images, facilitating more efficient decision-making and treatment planning. This has the potential to enhance patient care, reduce diagnosis times, and improve overall healthcare service delivery.

III. Key Recommendations

These recommendations aim to guide the development of policies, secure funding, and foster ongoing research collaborations to ensure the successful implementation and sustainability of the AI4D Africa Scholarship projects integrating health, artificial intelligence and machine learning.

Interdisciplinary collaboration

It is critical to support and encourage interdisciplinary collaboration among researchers, healthcare practitioners, and technology experts to foster a holistic approach to healthcare challenges. Projects such as the prediction model for COPD, surveillance for vector-borne diseases, and biomedical image captioning benefit from diverse expertise.

Technology scalability integration for accessibility

To enhance application of technologies arising from these research projects, it is important to push and advocate for the integration of advanced technologies, such as wearable devices, neural networks, and Internet of Things (IoT) solutions, into routine healthcare practices. Emphasize the potential of technology to enhance accessibility, improve patient care, and optimize healthcare delivery. It would also be important to consider the scalability and adaptability of technological solutions for deployment.

Data security and ethical considerations

Data security and ethics is paramount. For this reason, it is imperative to focus oe the critical importance of data security and ethical considerations, especially in projects involving sensitive healthcare information. Robust security measures and ethical frameworks should be put in place for IoT, verbal autopsy and privacy safeguards in biomedical image captioning.

Capacity building and training

For widespread adoption of these technologies, there should be initiatives for capacity building and training programs to empower healthcare professionals in effectively utilizing advanced technologies. This is crucial for the successful implementation and deployment of these technologies.

Standardization and guidelines

It is also important to develop standardized practices and guidelines in areas such as IoT security, verbal autopsy, and biomedical image captioning. Standardization ensures consistency, facilitates interoperability, and promotes best practices in healthcare technologies.

Public health education and awareness

Public health education and awareness of these technologies and solutions is important to ensure their successful integration. This includes educating healthcare providers, patients, and the public about the benefits and proper utilization of innovations like wearable devices and speech improvement frameworks.

Continuous research and iterative development

Finally, continuous research and iterative development, particularly in rapidly evolving fields such as artificial intelligence and IoT is critical. Regular updates and refinements based on ongoing research enhance the efficacy and applicability of technologies in diverse healthcare settings.

IV. Conclusion

The synthesis of these diverse research projects underscores the transformative potential of innovative technologies and methodologies in addressing critical challenges within healthcare and public health domains. Each project contributes uniquely to the advancement of medical practices and systems, showcasing the broad spectrum of applications for cutting-edge technologies. The research findings have the potential to improve patient outcomes, enhance public health strategies, and advance medical research on a global scale.

Synopsis of AI4D Africa Projects on Health

1. Prediction model and decision support system for chronic obstructive pulmonary disease (CORD) patients based on wearable pulse oximeter

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Country: Rwanda

Gender: Female

Supervisor: Dr. Philibert Nsengiyumva
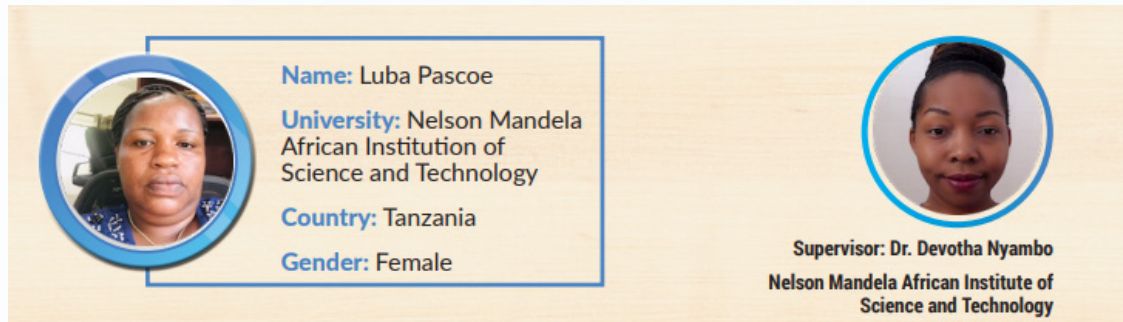University of Rwanda

Overview

Chronic Obstructive Pulmonary Disease (COPD) is a lung condition where the flow of air is restricted and can't be fully fixed. This disease causes specific changes in the lungs, affecting how they work and leading to various COPD symptoms. Doctors often use a system called GOLD staging, based on Forced Expiratory Volume (FEV1), which is a measure of lung function and is commonly used in pulmonary function tests (PFTs) to assess the amount of air a person can forcefully exhale from their lungs in one second. It is used to figure out how severe someone's COPD is. However, relying only on FEV1 doesn't always reflect how breathless or limited in activity someone feels. This makes it hard to create effective rules for treatment. Currently, some apps use simple questionnaires to assess daily symptoms, but they may not capture the severity of each symptom. This study introduces models that monitor patients remotely and can detect potential COPD-related issues. The goal is to create a personalized tele-health system that includes prediction models for classifying and managing COPD, using wearable devices like pulse oximeters. In this context, this research project aims to:

i.   provide a cloud computing hybrid AI-CDSS application to facilitate physicians to make decision on processed patients cases more intelligently;

ii. design an interpretable prediction model for COPD continuous monitoring to detect in real time exacerbation, subsequent exacerbations and COPD associated worrisome.

The research aims to reduce hospital admission for COPD patients, length of stay and mortality, save costs associated with the adoption of the system in healthcare settings and improve patient outcomes in COPD management.

Potential beneficiaries: COPD patients, healthcare providers, healthcare institutions, caregivers, public health authorities, insurance providers, and technology developers.

2. An agent-based model for surveillance of Dengue and Chikungunya in Sub-Saharan Africa

Name: Luba Pascoe

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Country: Tanzania

Gender: Female

Supervisor: Dr. Devotha Nyambo
Nelson Mandela African Institute of Science and Technology

Overview

Even though we know some things that cause infectious diseases, there are still unknown factors that make new diseases show up. This happens when we can't detect the diseases quickly, leading to delays in responding to emergencies. Predicting and understanding these emerging infectious diseases is a big challenge. Most solutions so far have focused on getting health data during outbreaks, but they haven't paid enough attention to the role of climate and the environment in spreading diseases. Nowadays, technology lets us analyze and model how diseases might change based on different conditions, policies, and rules. Agent-based modeling and simulation are useful tools for studying infectious diseases because they let us use intelligent agents (computer programs) to sense, plan, schedule, reason, and make decisions. This helps us better understand and prepare for infectious diseases. This research projects aims to:

i.   conceptualize the Agent-Based Model study domain on Dengue and Chikungunya diseases;

ii. develop Agent-Based Model and Simulation for surveillance of Dengue and Chikungunya in Tanzania;

iii. develop decision support tools to support differential diagnostics and surveillance for Dengue and Chikungunya in Tanzania.

Findings of this research will help improved detection and response to dengue fever outbreaks and also reduce mortality and morbidity due to dengue fever.

Potential Beneficiaries: The beneficiaries include public health authorities, policymakers, and communities in Sub-Saharan Africa. The agent-based model enhances disease surveillance, allowing for proactive planning and resource allocation. Early detection and response strategies can lead to effective public health interventions, reducing the impact of Dengue and Chikungunya on the population.

3. Ensemble convolutional neural network for multiclass, multilabel retinal disease detection

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Supervisor: Prof. Serestina Viriri
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Overview

There has been a significant increase in cases of sight threatening retinal diseases across the world, with developing countries the worst affected owing to compromised budgets to effectively detect and arrest progression. Deep Learning methods show promise in a bid to provide automated detection models but more needs to be done to provide methods that could match or surpass human level detection accuracies and gain trust and acceptance from the food and drug associations across the world. While Ensemble methods have proved to be successful in obtaining better performances in other machine learning applications, not much research has been done to explore the potential of ensemble methods for multiple retinal disease diagnosis. This research aims to:

i. review literature to understand state of the art methods for detection of multiple retinal diseases;

ii. acquire datasets for model development;

iii. pre-process the datasets to ready them for model development;

iv. train ensemble Convolutional Neural Networks on the datasets;

v. evaluate the performance of the ensemble models.

Findings of this research will help improve the accuracy and reliability of disease detection, leading to early and accurate diagnosis for patients, enhance patient outcomes through early detection of retinal diseases and improved access to health care and provide an affordable and easy to use solution that can be deployed in resource-constrained healthcare environments.

Potential beneficiaries: Ophthalmologists, medical imaging professionals, and patients would benefit from more accurate and comprehensive retinal disease detection. The ensemble convolutional neural network enhances the reliability of automated diagnostics, aiding healthcare providers in making informed decisions about treatment plans. Patients benefit from earlier detection and intervention for retinal conditions.

4. Internet of Things (IoT) security for e-health in developing countries

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Overview

Internet of Things (IoT) refers to the interconnected network of physical devices, vehicles, appliances, and other objects embedded with sensors, software, and network connectivity, allowing them to collect and exchange data. The goal of IoT is to enable these devices to communicate with each other, often through the internet, to facilitate automation, monitoring, and control. With a large number of IoT applications comes risks of security and privacy. Without a reliable and interoperable IoT ecosystem, emerging IoT applications cannot achieve high demand and thus do not operate at their full potential. In addition the Internet, cellular networks and Wireless Sensor Network (WSNs) IoT have unique security challenges such as privacy issues related to authentication, management, information storage. Device security is about protecting IoT devices from attacks, while data security is related to protecting the integrity and confidentiality of data generated by IoT sensors and other monitoring instruments. However, this field has suffered various attacks targeting medical systems. Analysis of previous security and privacy systems of IoT have been discussed but not actually related to Internet of Medical Things (IoMT). Various intrusion detection methods and authentication/authorization have been discussed to ensure a secure IoT environment with little regard to their application to IoT. This research aims to develop and optimize security mechanisms to ensure the privacy and confidentiality of sensitive health data transmitted and stored within IoT devices and systems. Specifically, this research aims to:

i.   develop a comprehensive bibliographic study of the state of IoT security in the medical field and medical data;

ii.   study of new security approaches, their integration in the IoT (limited resource) and the securing of medical data using intelligent and light cryptographic techniques;

iii. study the effects of blockchain for the security of IoMT and medical data;

iv.   develop customized blockchain systems of record with enhanced privacy features and limited accessibility.

The project expects to improve safety of patient medical information and develop a more secure and resilient IoT infrastructure for e-health services.

Potential beneficiaries: Developing countries' e-health systems, healthcare providers, and patients stand to benefit from enhanced IoT security. Strengthening security measures in e-health systems ensures the confidentiality and integrity of patient data. This benefits healthcare providers by fostering trust in digital health platforms and improves patient confidence in using e-health services.

5. Speech improvement framework using long short-term memory neural network and dynamic time warping to improve Kenyatta National Hospital health records retrieval

Name: Mercy Kimani

University: Jomo Kenyatta University of Agriculture and Technology

Country: Kenya

Gender: Female

Supervisor: Dr. Lawrence Nderu
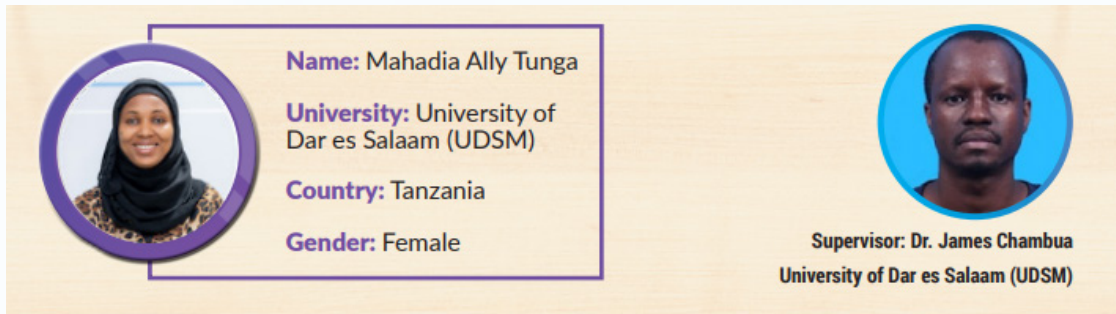Jomo Kenyatta University of Agriculture and Technology (JKUAT)

Overview

Speech recognition is the capability of a machine program to identify spoken word and convert it to a readable format. It helps to recognize vocalized words to finish a task that has been assigned or decipher the spoken word into text. In the sector of health care, the providers regularly use speech recognition to generate medical documentation. This has in a great way enhanced and transformed the way healthcare providers execute their day-to-day tasks thanks to the several improvements that have been developed in the recent years. Currently in the area of speech signal processing there is still a challenge on speech improvement. Reviewed literature on speech recognition present numerous speech improvement algorithms which can be categorized into filtering, spectral restoration and speech model techniques (Liu et al., 2019). These methods are widely used, however they are not very competitive in late latency reduction, increased accuracy and give poor output in a noisy environment. With ongoing development of neural networks in deep learning, this study will develop a framework based on long short-term memory neural network and dynamic time warping algorithm which will be tested and validated using data obtained from health records. The research aims to:

i. investigate and review existing literature on Long Short-term Memory Neural Network and Dynamic Time Warping for speech recognition;

ii. develop speech improvement framework based on Long Short-Term memory Neural Network and Dynamic Time Warping;

iii. implement the long short-term memory and dynamic time warping framework and evaluate the accuracy level and latency;

iv. test and validate the developed framework for speech recognition using Kenyatta National Hospital health records data.

Potential Beneficiaries: Healthcare professionals, medical transcriptionists, and patients would benefit from improved speech recognition and health records retrieval. The framework enhances the accuracy and efficiency of transcribing spoken medical information, streamlining the retrieval process and contributing to more effective healthcare communication.

6. The hybrid approach in verbal autopsy cause of death determination

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Country: Tanzania

Gender: Female

Supervisor: Dr. James Chambua
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Overview

Physicians are being used to analyze VA data and establish causes of death. However, due to the high volume of cases to be dealt with by physicians, the process becomes sedate, costly and over time the quality is questionable. In the struggle to speed up the process, lower cost, and burden, multiple methods have been proposed to automate the assignment of causes of death from VA data using machine learning models such as Naive Bayes, InterVA, InsilicoVA, and Tariff. The existing models of predicting the individual causes of death produce results with limited accuracy far compared to physicians. These models ignore substantial amounts of data by assigning causes of death based only on the presence of symptoms or signs and disregarding information on medical history and circumstances preceding death. Limited accuracy makes the existing models ineffective. Thus, LMICs fail to reflect the country's condition of morbidity and associated factors resulting in poor functioning health systems. The main objective of this study is to develop a verbal autopsy-based hybrid data analytic model for improved determination of the cause of death in order to produce accurate mortality statistics. This research project set out to:

i.   establish the most significant features for improved prediction of cause of death using VA data;

ii.   build a hybrid model for determining the cause of death based on the established features;

iii.   validate the performance of the proposed model.

The study will help improve accuracy of cause of death determination compared to traditional methods and Enhance consistency of cause of death determinations across different settings and contexts.

Potential Beneficiaries: Communities, public health researchers, and policymakers in regions with limited access to formal medical examinations are likely to benefit. The hybrid approach improves the accuracy of cause of death determinations in verbal autopsies, providing valuable data for understanding disease patterns, developing health policies, and allocating resources effectively.

7. Automatic generation of biomedical image captions (biomedical images captioning)

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Gender: Male

Prof. Norbert Tsopze

Overview

Nowadays, with population growth, the food industry offers less and less organic food, industry in general increases the rate of environmental pollution, also, population growth increases road traffic and at the same time traffic accidents. All this mixture exposes populations to chronic type pathologies requiring the intervention of cutting-edge medical techniques such as radiology. These pathologies are mostly related to the lungs (Tuberculosis, Pneumonia, etc.), the brain (stroke, Epilepsy, etc.), the bones (Bone fractures, etc.), etc. To be able to identify them, the experts in each field use biomedical images from cutting-edge radiology devices, which takes a long time to analyze and often at enormous costs. This exercise is not only susceptible to human error but also favors patients in urban areas where experts are often found. Therefore, this study aims to:

i.   experiment a generative adversarial network (GAN) type architecture on a biomedical image dataset and evaluate (quantitative and qualitative evaluation) its performance in order to be able to modify the internal structure of the model if possible for a possible improvement;

ii.   experiment with a model based on an Encoder-Decoder architecture with attention to the input image and proceed to an evaluation (quantitative and qualitative) in order to be able to modify the internal structure of the model if necessary for possible improvement;

iii. propose a hybrid architecture which will take advantage of the best of the two methods stated in 1 and 2 and will proceed to an evaluation of the performances of this one compared to those of the two other methods of which it will ensue.

The study expects to develop a new captioning model specifically tailored for biomedical images, enhance the accuracy and quality of generated captions for biomedical images and create evaluation metrics and benchmarking methodologies for biomedical image captioning.

Potential Beneficiaries: Radiologists, healthcare professionals, and medical researchers are the primary beneficiaries.