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Article

Machine learning technology for good health and well-being for sustainable human security in South Africa

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Abstract: The failure to achieve sustainable development in South Africa is due to the inability to deliver quality and adequate health services that would lead to the achievement of sustainable human security. As we live in an era of digital technology, Machine Learning (ML) has not yet permeated the healthcare sector in South Africa. Its effects on promoting quality health services for sustainable human security have not attracted much academic attention in South Africa and across the African continent. Hospitals still face numerous challenges that have hindered achieving adequate health services. For this reason, the healthcare sector in South Africa continues to suffer from numerous challenges, including inadequate finances, poor governance, long waiting times, shortages of medical staff, and poor medical record keeping. These challenges have affected health services provision and thus pose threats to the achievement of sustainable security. The paper found that ML technology enables adequate health services that alleviate disease burden and thus lead to sustainable human security. It speeds up medical treatment, enabling medical workers to deliver health services accurately and reducing the financial cost of medical treatments. ML assists in the prevention of pandemic outbreaks and as well as monitoring their potential epidemic outbreaks. It protects and keeps medical records and makes them readily available when patients visit any hospital. The paper used a qualitative research design that used an exploratory approach to collect and analyse data.

Keywords: machine learning; sustainable human development; good health and wellbeing; sustainable human security and South Africa

1. Introduction

Sustainable human security, being the ability to protect and promote human survival, sustainable human development, human dignity, and human sustainability, depends on people's good health and well-being. The failure to understand the role of good health and well-being in promoting sustainable human security for sustainable development has received scant academic attention in South Africa. It has posed immense threats to security by leading to health service protests in various local municipalities in South Africa. It has also made achieving good health and well-being difficult and poses significant threats to national security through service delivery protests. It has been noted that services in public health institutions are failing to meet basic standards of care and patient expectations (National Department of Health, 2012, p. 4). This failure has affected delivering adequate health services that lead to good health and well-being. It has also continued to make citizens lose trust and hope in the healthcare system and see it as incapable of delivering health services that alleviate diseases for the achievement of human survival, human development, human dignity, and human sustainability. Koelble and Siddle (2014, p. 1118) describe the healthcare system in South Africa as ruined and in serious need of repair.

Machine learning (ML) algorithms are one the Artificial Intelligence (AI) technologies that learn from the data and concentrate rules from the data, then use it to assess new data to achieve new insights that help address many problems ranging from classification and regression to clustering. In modern society, ML algorithms are the basis for granting loans, online product recommendations, and social media friend suggestions (Adadi and Berrada, 2018). ML can help unlock data values, free up high-value work, improve services for citizen queries, enhance predictive capability for decision-making, and thus fuel innovative public services (Eggers et al., 2017). Scholars presented the nascent status of governmental ML applications (Sun and Medaglia, 2019) and the scarcity of related research (Gomes et al., 2019; Zuiderwijk et al., 2021). However, in South Africa, ML algorithms have not been used to leap their potential in promoting health services in the public and private sectors. This has led to the knowledge gap and has affected the possibility of providing adequate health services that lead to good health and well-being for sustainable human security. Zuidermijk et al. (2019) have presented that such a failure to apply ML algorithms is an effect of less AI expertise within the public sector. Furthermore, this failure is caused by the lower expertise of public servants in governing the use of digital technologies in public services. It is also caused by a lack of understanding that sustainable security interacts with other securities that make human security to make human security sustainable in Africa.

Good health and well-being are the third Sustainable Development Goals closely related to sustainable human security. Good health and well-being result from delivering adequate health services is the basis of all human securities. This is to say that the existence and functionality of the other six human securities (economic, health, environmental, personal, community, and political) depend on the delivery of adequate health services. This is because a weak and diseased population becomes unable to work, making it impossible for the population to achieve sustainable livelihoods. Unstable health security resulting from a sick population and the existence of a heavy burden of disease pose immense threats to livelihoods, causing more human insecurities that deprive people of their freedom from wants and fear. Good health is a significant pillar of sustainable human development because it influences people's well-being, strengthening their livelihoods and reinforcing their possibility of achieving sustainable human security (Stoeva, 2020). There are numerous links between human insecurity and infectious disease outbreaks (Institute of Medicine, 1992; Institute of Medicine, 1997). Achieving sustainable human security that promotes good health and well-being in South Africa has become a critical challenge. The lack of good health and well-being triggers political violence and promotes the recurrence of former conflicts that have been addressed before (The White House, 1994).

As there are links between political violence and health insecurity, it can be said that infectious diseases and disease burden are significant challenges in South Africa that contribute to a slowdown in economic growth. A stagnant economy is a threat to achieving sustainable human security because it breeds all sorts of violence, starting with family and social protests to political violence. Armour (2008) argued that an economic slump does not only cause family violence but is also implicated as a cause of familial violence and the breakup of families. Inadequate and disparities in financial

income have led to homicides, suicide killings, and crimes (Winton et al., 2008) and have triggered deadly violence in society, thus posing threats to human security. Increased financial stress affects the achieving sustainable health security and promotes domestic and national violence that affects national security.

Achieving sustainable human security that leads to social order, rule of law, and stability depends on good health and well-being. Sustainable human security, in the context of good health and well-being, means a situation that exists when citizens receive quality and adequate health services that cure their diseases from the root causes with protective and preventative mechanisms that protect them from any other diseases so that they are free from fear and wants. This means that people can live with fewer diseases and are empowered to control and manage those diseases if they occur so that they can continue living with dignity. Poor healthcare services destabilize the vital core of human lives because these services do not allow the possibility of achieving good health and well-being, thus undermining the ability to achieve sustainable human security. Healthcare systems in Africa are unworkable conditions with poor health outcomes (Oleribe et al., 2019).

Providing health services that lead to good health and well-being depends on the nature of the healthcare systems in place and the support those systems receive from the government. Unfortunately, healthcare systems in South Africa have suffered from colossal neglect and a lack of resources that have hindered achieving good health and well-being for sustainable human security. Scholars have argued that for so many years, healthcare systems in Africa have suffered from issues that result from a lack of solid healthcare institutions, lack of adequate human resources, and financial, technical, and political developments Roncarolo et al. (2013); Oleribe et al. (2019). Petersen et al. (2017) said numerous African countries cannot meet the fundamental requirements for proper healthcare systems. Marais and Petersen (2015) and Oleribe et al. (2019) argued that poor governance and lack of adequate funds to support healthcare systems in Africa hinder the provision of adequate health services that would promote good health.

Moreover, in South Africa, Maphumulo and Bhengu (2019, pp. 2–3) argued that the healthcare system continues to suffer from "prolonged waiting time because of shortage of human resources, adverse events, poor hygiene, and poor infection control measures, increased litigation because of avoidable errors, shortage of resources in medicine and equipment and poor recordkeeping." These challenges have resulted from weak public health leadership, inadequate health legislation, and reliance on manual medical records. It also results from a lack of sufficient health workers, corruption within the healthcare system, and failure to predict the outbreaks of pandemics. These challenges have affected the provision of adequate health services that would lead to good health and well-being. Achieving sustainable human security depends on people's ability to receive adequate health services. This would result from a robust healthcare system. Such a robust healthcare system would be achievable using innovative technology like ML. Applying ML technology to the healthcare system would break the current impasse that hinders adequate health services in South Africa.

Obermeyer et al. (2016) and Rajkomar et al. (2018) noted that ML technology is effective when used in the hospitals because it predicts patient readmissions, mortality rates, and disease onset based on electronic health records (EHR) data. The ML

predictive ability improves patient outcomes because it enables medical practitioners to carry out early intervention and personalized treatment plans that better the health of the patients (Aliper et al., 2016). ML can also be used in drug discovery, accelerate the identification of novel therapeutics and optimize drugs for the patients (Shickel et al., 2018). It has been further noted that the use of ML algorithms can help to analyse molecular data, predict drug-target interactions, and design personalized treatment regimens (Angermueller et al., 2020). The paper found that ML used in healthcare services improves and ensures drug efficacy, reduces financial costs, and promote accurate precision medicine. It would support and assist healthcare providers in diagnosis, treatment planning, and patient management. This has been pointed out by Caruana et al. (2015) and Shickel et al. (2018) that ML enable medical practitioners to analyse diverse healthcare data sources, such as EHR data, medical imaging, and genomic data, to generate actionable insights and recommendations. The paper thus showed that the use of ML technologies in healthcare systems ensures good governance and decision-making, enhances and improves workflow efficiency, as well as reducing medical errors, thus lead to the delivery of adequate health services that promote good health and well-being for sustainable development. However, the use of such technologies has not been given full attention it deserves in South Africa. It therefore presents a gap that has hindered the delivery of quality health services for sustainable development in South Africa.

By recognising the knowledge gap, this paper aims to contribute to debates about interactions between health security and people's livelihoods and about the application of ML technology in the public sector to transform the healthcare system to promote adequate good health and well-being that leads to sustainable human security in Africa. It strives to serve as a brief primer based on a literature review to answer why ML should be used in the public healthcare system to achieve healthcare services that lead to sustainable health security. It synthesizes research and cases in action as its theoretical foundation to illustrate potential ML usage in the public sector as a proposal for future research directions. It also helps ML experts and healthcare workers understand the specific problems of healthcare provision in Africa, the linkages between health security and other securities, and the need to apply ML technology to healthcare systems.

Thus, the paper is structured as follows: While the first section provides a lengthy introduction and background which explained the research problem and the aim of this paper, the second section explained the research methodology that was used to collect and analyse data. The third section is a literature review investigating the challenges of healthcare systems in South Africa. It also examined the challenges of sustainable human development, the threats the disease burden poses on human development, and the interactions between good health and well-being and sustainable human development. The fourth section explained the research methodology and techniques for collecting and analyzing data. The fifth section explained a theoretical framework that underpins this article. The sixth section consisted of discussions of the findings. Concluding policy advice and research recommendations to maximize the potential application of ML technology to healthcare in South Africa are given in the last part.

2. Research methodology

The study used qualitative research methodology techniques to collect and analyse data. The use of this methodology enabled to understand the ML practices in public healthcare systems and its effects on improving the quality of healthcare services (Streubert and Carpenter, 2002). The methodology also enabled the researcher to assess lived experiences between the service providers and receivers, learn more about how people think, and increased a researcher's view of the role of ML on goof health and wellbeing and as well as on the sustainable human security (Bliss, 2016). Qualitative methodology enabled the researcher to assess and human experience in daily life focusing on those actual experiences to learn more about how individuals perceive those experiences (Delve and Limpaecher, 2022). The experiences were the failure of the South African health systems to deliver quality health services and the impact those services on the good health and health thus fail to achieve human security that would enable the realisation of sustainable development in South Africa. Burns and Grove (2009) argued that qualitative research is a systematic and subjective approach to highlight and explain daily life experiences, and to further give them proper meaning.

The data adopted was secondary and was collected from literature review through desktop research. The use of a secondary data was useful and focused on the readings from sustainable human development, sustainability, Fourth Industrial Revolution and ML, human security, good health and wellbeing. Data sources included but were not limited to journal articles, credible online sources, unpublished dissertations, policy briefs and online newspaper sources that spoke to the research aim of the paper. The data was analysed in narrative form through reflections, arguments and different narratives that explain the role of ML in promoting good health and wellbeing, as well as the role of good health and wellbeing in achieving sustainable human security thus achieve sustainable development in South Africa and the challenges hindering the possibility of delivering quality health services. The paper used exploratory research technique to review the literature on ML and healthcare services to understand the factors that hinder the delivery of quality and adequate health services. Exploratory research technique was used because it is a valuable means of understanding what is happening; to seek new insights; to ask questions and to assess phenomenon in a new light (Yin, 1994). This technique was used to develop initial ideas and insights and to provide new insights (Aakeret et al., 2007) on the effects of ML on the provision of quality health services that promote good health and wellbeing for a sustainable human development. This technique became significant because it helped to identify problems within the South Africa healthcare systems, define the problem more precisely and identify key data requirements (Kinnear and Taylor, 1996) needed to answer the aim and objective of this paper. The exploratory research technique was undertaken in this paper to explore unknown areas of the ML and to assess how these areas used in public healthcare can improve the delivery of adequate health services that lead to good health and well-being for a realisation of sustainable development. Therefore, exploratory research technique illuminated the effects of delivering inadequate health services on good health and wellbeing and explained its role for achieving sustainable development in South Africa.

3. Literature review

3.1. Healthcare system defined

A healthcare system comprises several institutional players, each playing its role with a common shared objective of providing wholesome health service to patients. The WHO (2007) states that a health system comprises all organizations, people, and actions that aim to promote, restore, or maintain health. It includes efforts to influence determinants of health as well as more direct activities that improve health. Cieza (2019) argues that a health system is more than the pyramid of publicly owned facilities that deliver personal health services; it includes the institutions, people, and resources involved in delivering health care to individuals.

It is important to note that a good health system is built on trained health professionals motivated to work passionately to save lives. It is argued that a health system must be informed by a "well-maintained infrastructure, and a reliable supply of medicines and technologies, backed by adequate funding, strong health plans, and evidence-based policies" (Cieza, 2019, p. 6). However, healthcare differs from nation to nation depending on the level of economic prosperity and the willingness of political leaders to build and maintain well-structured health policies. There are stable health institutions and economic prosperity in developing countries, where healthcare systems are a priority and of great concern to everyone. Strong and working healthcare systems must exist in every country, whether private, public, or mixed (Cieza, 2019). Healthcare systems face challenges concerning quality, delivery, and cost of services (Cieza, 2019). Many developing countries are experimenting with challenges to the healthcare system resulting from weak health policies in place (Grant et al., 2013). A health system is thus understood as one great system in which different health players exist, either as elements or sub-systems.

3.2. The challenges of healthcare system in South Africa

Delivering adequate health services that lead to good health and well-being for sustainable human security in South Africa has been hindered by numerous challenges. These challenges that have jeopardized the healthcare system in South Africa include prolonged waiting time because of a shortage of human resources, adverse events, poor hygiene, poor infection control measures, increased litigation because of avoidable errors, shortage of resources in medicine and equipment, and poor recordkeeping (Maphumulo and Bhengu, 2019, pp. 2–3). They also include inadequate budgetary allocations to health and poor governance of the healthcare system (Kirigia and Wambebe, 2006; Kirigia et al., 2007).

3.2.1. Inadequate financing of healthcare

It is a significant challenge that has hindered the delivery of health services that would lead to the achievement of good health and well-being in Africa. Inadequate financing of the healthcare system in Africa is a significant problem that has increased the disease burden and caused insecurity and the failure to achieve Sustainable Development Goals. Oleribe, et al. (2016) have argued that inadequate human resources are the foremost leading challenge in the healthcare system sector in Africa. There is also poor availability of healthcare workers to deliver services, resulting from

worker strikes, attendance at private practice (rather than public hospitals), internal migration to big cities, and poor attitude to work WHO (2007). South Africa faces the main challenge of a shortage of human resources for health. However, every component of the healthcare system and health services delivery depends on the people who provide the services (WHO, 2007). Omaswa (2014) argued that healthcare provision depends on solid human resources, promoting a strong workforce.

3.2.2. Poor governance in the healthcare sector

A healthcare system in any country depends on strong leadership and governance to deliver health services to the people. Weak governance and administration in the public healthcare system have led to a vital decline in health service delivery. It, therefore, means that the government plays a significant role in achieving efficient governance for public healthcare that ensures that quality health services are delivered to the people shortly to save their lives. Governance for healthcare in Africa remains a critical issue that hinders the delivery of adequate health services. Poor governance of the healthcare system in Africa is the reason for the delivery of poor health services. Dye and Garman (2015) argue that healthcare managers' unfamiliarity with governance techniques hinders the effectiveness of healthcare services. Good governance and a qualified healthcare working team can reduce conflicts within the system, improve efficiency and productivity, enhance staff satisfaction, and advance healthcare system performance (Mosadeghrad, 2013), which provides health services that lead to good health and well-being of the people.

3.2.3. Prolonged waiting time because of shortage of human resources

A significant weakness in sub-Saharan African health systems is inadequate human resources. Africa is said to have less than one health worker per 1000 people compared to 10 per 1000 people in Europe (Fonn et al., 2011). Barron and Padarath (2017) noted that health problems in South Africa are worsened by the unequal distribution of health professionals between the private and public sectors and the unequal distribution of public sector health professionals among the provinces. In a study conducted by Tana (2013), participants affirmed the insufficiency and inadequacy of health workers, which they described as leading to physical and mental exhaustion and, in some cases, to further deterioration of their medical condition.

3.2.4. Poor record-keeping

Kama (2017) points out that poor record-keeping causes unnecessary patient delays. Sometimes, patients' folders are missing or lost, and instead of healthcare workers explaining this to the patient, they let the patient wait for Kama (2017). In the worst scenarios, the medical history of the patient is lost, which can create further complications leading to incorrect diagnosis and, in some cases, death of the patient Kama (2017). As reported by the Mercury (9 April 2015), the Pietermaritzburg High Court ordered a district hospital in KwaZulu-Natal to hand over medical records to the patient's attorney in a case where the patient had in July 2006 delivered twins in the hospital, allegedly losing one of the twins while the surviving twin suffered from cerebral palsy because of hospital neglect (Regchand, 2015). The WHO (2007) has suggested a framework that explains healthcare systems in six building blocks. These building blocks include service delivery, healthcare workforce, healthcare information

systems, medicines and technologies, financing, and leadership/governance WHO (2007).

3.3. Sustainable human security

Sustainable human security is "protecting the state, its people, institutions, and values from external attacks" (Roff, 2017, p. 3). Human security offers much to this vibrant field of sustainable development. Sustainable human security highlights the social dimension of sustainable human development based on sustainable health. Sustainable health is based on three pillars: environment, economy, and society. Sound and sustainable health strengthens the environment and enables the population to be vibrant to sustain people's economic income. Sustainable health also impacts society positively because a peaceful society is based on a health system that promotes and leads to adequate health services. The efforts and initiatives to advance human security through strengthening healthcare institutions and enabling them to provide quality health services are paramount. It means that sustainable human security is strongly dependent on the provision of quality and adequate health services.

Sustainable human security stems from sustainable development and encompasses respect for human rights, dignity, and growth. It also stems from the ability of the people to access sustainable income, with efficient health and welfare to work to overcome disease burden. It means that sustainable human security depends on the ability of the people to achieve sustainable livelihoods. Roff (2017) argued that the features of sustainable human security include planning and empowerment. Planning concerns the ability of ordinary citizens to respond quickly and appropriately to situations that might threaten their livelihoods. It is also concerned with the people's ability to address and handle complex cases such as diseases with the ability to access quality health services that promote their well-being and welfare. Moreover, sustainable human security concerns people's empowerment Roff (2017). There are links between human security and empowerment. It is because enabling is for the people and is linked to human growth and development, making it an ongoing process.

Empowerment is people-centered, involving mutual respect and relationship, critical reflection, caring, and group participation. Empowerment is critical in human security because it enables people to be free from fear and wants and addresses inequality that might lead to uncertainty. Empowerment promotes an equal share of valued resources and gains greater access to and control over those resources (Perkins and Zimmerman, 1995). It is also a process that enables people to gain control over their lives, democratic participation in the life of their community, and a critical understanding of their environment (Perkins and Zimmerman, 1995). Empowerment leads to sustainable human security by involving active participation, critical reflection, awareness, and understanding among and between the citizens. It also plays a significant role in raising consciousness about the influence of powerful political and economic structures and interests. It enables people to access and control essential decisions and resources, enabling them to participate in governance (Homan, 2008).

Through empowerment, all forms and sources of inequality and imbalances that promote and sustain oppression throughout society that lead to human insecurities are identified and understood in society (Perkins et al., 2007). Empowerment liberates

oppressed individuals to reach their full potential and motivates working or unemployed people. It also houses the homeless and prevents discrimination in society Perkins et al. (2007). Human security is sustainable through empowerment because it focuses on ordinary people's assumptions and attitudes and motivates people, whether employees or employers, to work closely and collaboratively (Pigg, 2002). Motivation empowers people in society to be self-help; it enables them to move from illness to wellness, from ameliorating problems and deficits. It transforms and liberates oneself and the community toward competence (Pigg, 2002).

3.4. Interactions between healthcare and human security

Human security involves economic, food scarcity, health, environmental, personal, community, and political. However, among the seven dimensions or categories, health is paramount because all the others lean on it (Gutlove and Thompson, 2003). For example, a weak population that suffers from diseases cannot have the ability to work to achieve a sustainable economic income, protect the environment, and be free from fear and wants. Healthcare is essential to human security because it protects the vital core of all human lives. Healthcare also enables people to achieve their freedoms, which are free from fear and want to intensify their human growth. It has been argued that without good health and well-being, people would not have the ability to exercise their freedoms (Gutlove and Thompson, 2003). It means that people's freedoms that lead to sustainable human security depend on their health status. It is to say that health security is directly linked to the people because it enables people to exercise their freedom to pursue what they value in life.

Chen, Leaning, and Narasimhan (2003) link health concerns to six human security dimensions. Adequate delivery of health services to the citizens enables them to realize and achieve economic, food, personal, community, and political security. The WHO (2013) argued that achieving adequate health services leads to people's happiness, energy to work, and harmonious relations, thus promoting the security of all in society. The WHO (2013) further argued that all people's health is fundamental to attaining sustainable human security, making sustainable peace and security a reality. Sustainable security points to sustainable health and welfare and their contributions to a healthy population that strengthen human stability rather than secure health. This is because, mainly in Africa, securing health has been for the class elite and wealthy people, while poor people are left behind with a heavy burden of diseases. Unfortunately, the literature has not developed adequate health services and their role in leading to sustainable security. Achieving sustainable health and delivering adequate health services that promote the sustainable welfare of the people leads to sustainable peace and security in society. It, therefore, leads to sustainable human security and acts as a prevention mechanism. The WHO (2007) argued that preventing violence can be made possible if healthcare systems that provide quality health services that lead to good health and well-being are a priority.

As seen in Africa, a lack of adequate and quality health services can ignite political violence. For example, delivering inadequate health services in Burundi, Somalia, and Zimbabwe has exacerbated political violence. The prevalence of poor healthcare services in South Africa's local municipalities has intensified social

protests and strikes that threaten human security. It has been argued that most conflicts occurring in Africa are intensified by the lack of adequate and quality healthcare (Jaitman, 2015). This means people protest or venture into the streets to ask for their right to access adequate and quality health services. Moreover, it has been argued that stress caused by suffering from disease and the worsening of living conditions contributes to an increase in political conflicts and uncertainties WHO (2007).

It has been further argued that for delivering adequate healthcare services that lead to sustainable human security, there must be strong public policies that promote adequate provision of services. These public policies must strengthen public health institutions WHO (2013) and the use of digital technologies in the healthcare sector. However, at the time of writing this paper, there is a gap between health insecurities or threats in South Africa and the inability of the current healthcare systems to address them. Therefore, this poses immense threats to human security, making the achievement of sustainable human security in Africa impossible.

3.5. Role of ML in healthcare systems

The concept of ML was coined by Arthur Samuel and appeared in the literature in 1950. It is a sub-technology of Artificial Intelligence (AI) (Samuel, 1959). ML refers to "various statistical techniques that allow computers to learn from experience without being explicitly programmed" Javaid et al. (2022). Jabbar et al. (2018) define ML as developing algorithms to learn from data. Scholars have noted that this learning typically changes how an algorithm works (Javaid et al., 2022; Schapire, 2008). The ML system applied to service delivery recognizes faces because it studies the collection of photographs, which enables it to depict and describe various people. The ML system is subdivided into unsupervised learning and supervised learning (Javaid et al., 2022). In service delivery, the ML system relies on robots, giving them the power and ability to learn and work independently without human assistance (Schapire, 2008; Toh and Brody, 2021). This means the ML system is efficient and timely in Africa because its functions do not need human intervention.

ML is an umbrella term encompassing various algorithms for natural language processing, data mining, image processing, and predictive analytics. It is often called algorithms and used interchangeably with Artificial Intelligence and automated decision-making European Commission (2018). ML segregates different data types to recognize patterns and attain a specific goal. ML enables computers to learn automatically from experience instead of relying on manually, explicitly programmed rules and generalizing the acquired knowledge to new settings (Beck et al., 2018) It can automate repetitive tasks, handle the analysis of large datasets, and provide predictive information in the public sector (Beck et al., 2018). ML algorithms can extract meaningful information from more complex data than text (Beck et al., 2018). Gebru et al. (2017) trained an ML model that extracts features from the image of Google Street View in 200 US cities to estimate socioeconomic characteristics. This model is more accurate in predicting household income and thus can reduce the cost of labor-intensive door-to-door censure surveys and help solve the lag of demographic changes between two surveys (Beck et al., 2018).

ML enables AI to take place and allows the imitation of human behavior through self-learning ML algorithms (Javaid et al., 2022). From a healthcare service delivery overview, ML works without any intervention of middle persons who promote corrupt arrangements and deals that affect the quality of health services. ML is available in modern society. For example, the Google system uses ML, and every time an individual searches on Google, he finds information. People who use technologies like Alexa, Siri and Television Channels such as Showmax and Netflix to watch shows are all possible due to ML (Mantari et al., 2020). Furthermore, ML has already demonstrated considerable potential to enhance the effectiveness and accuracy of many decision-making scenarios ranging from medical diagnosis, granting mortgages, tax evasion, and terrorist activity identification (Mantari et al., 2020).

Role of machine learning in modern society

The overall role of ML is to make life simpler for human beings. Instead of codifying knowledge into computers, ML seeks to automatically learn meaningful relationships and patterns from examples and observations (Bishop, 2006). The best scenario for better ML is where it is not complicated for people to work behind the scenes and promotes efficiency and effectiveness (Bishop, 2006). Today, ML algorithms are the basis for granting loans, online product recommendations, and social media friend suggestions (Adadi and Berrada, 2018). The potential of ML in the public sphere is grounded in the tremendous data availability and policy prediction needs of this field (Kononenko, 2001). The use of ML in policymaking enhances and increases transparency and accountability. Diakopoulos (2016) argued that transparency and accountability are interlinked, reinforcing the other. ML promotes transparency in the decision-making process to enable accountability and public participation Diakopoulos (2016). The use of ML in the public service sector allows policymakers and citizens to track the entire procedure and detect responsibilities when some failures in service delivery are imminent. The essence of ML is continuous automatic improvement through experience. ML has been used in science, technology, and commerce. ML combines various disciplines, such as computer science and Information Technology, statistics, psychology, neuroscience, educational practices, organizational behavior, economics, and mathematics (Jordan and Mitchell, 2015). Those disciplines that house ML are illustrated in the diagram below **Figure 1**:

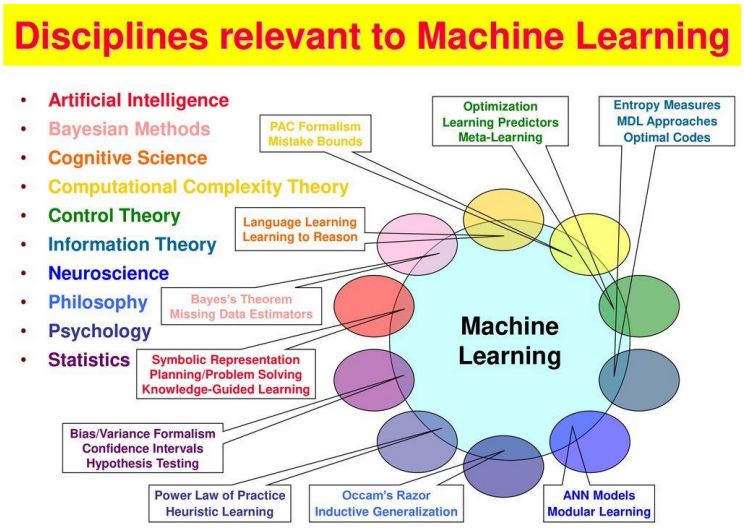

Figure 1. Key Discipline relevant to Machine Learning.
Source: Mitchel (1997).

It has been argued that advanced ML use in modern businesses has enabled the rise of intelligent systems with human-like cognitive capacity Shrestha et al. (2021). ML has penetrated daily businesses and personal lives and has shaped the networked interactions on electronic markets, thus enabling the smooth delivery of services. It enabled companies to increase their ability to make decisions that promote productivity, positive engagement with employees, and retention (Shrestha et al., 2021). ML has enabled training that has promoted service providers and receivers to understand the nature of services they are supposed to receive and how to receive those Fischer et al. (2020). ML has enabled trading agents to shake traditional finance trading markets and has enabled all-inclusive services that satisfy citizens (Jayanth et al., 2018).

3.6. The branches of machine learning

In its application to modern society to enhance service provisions, ML has three branches: supervised learning, unsupervised learning, and reinforcement learning.

3.6.1. Supervised machine learning

Supervised ML uses training data known as labelled data (Toh and Brody, 2021). It is important to note that the training data has one or more inputs and has a labelled output (Toh and Brody, 2021). Models use these labelled results to assess themselves during training, to improve the prediction of new data, for example, a set of test data) (Brewka, 1996). Usually, supervised learning models focus on classification and regression algorithms (Alpaydin, 2014). It is vital to note that in most healthcare systems in Africa, classification has become a common problem that hinders the provision of adequate health services in numerous hospitals. ML can help address these classification problems and promote efficient health services for citizens. Toh and Brody (2021) have argued that diagnosing a patient involves a doctor classifying the ailment given a particular set of symptoms in numerous clinical settings. They also argued that regression problems tend to predict numerical results like the estimated length of stay in a hospital given a specific set of data such as vital signs, medical

history, and weight (Toh and Brody, 2021). Supervised learning methods include spam classifiers, medical diagnostic systems, and face recognition systems over images. Thus, these supervised learning systems make predictions using learned mapping (Jordan and Mitchell, 2015).

3.6.2. Unsupervised machine learning

Unsupervised ML uses unlabelled data to find patterns within the data itself (Libbrecht and Noble, 2015). Unsupervised data makes assumptions about the structural characteristics of unlabeled data (Jordan and Mitchell, 2015). Unsupervised ML relies on the algorithms to function and perform in any service delivery setting. ML algorithms learn from the data and concentrate rules from the data, then apply the learned insight to assess new data, allowing their gained insights to solve many distinct problems ranging from classification and regression to clustering (Adadi and Berrada, 2018). It has been argued that its algorithms work marvelously and excellently in clustering data into relevant groups and enable the detection of latent characteristics that are not easily visible (Toh and Brody, 2021). It is important to note that in its working, unsupervised ML leans on the computationally intensive and requires a substantial amount of data to perform (Längkvist et al., 2014). The most common and well-known algorithms are K-means clustering and Deep Learning (DL), and can be supervised (Alpaydin, 2014). It is vital to note that the algorithms also perform association tasks, such as clustering, and are considered unsupervised because they do not depend on human inputs or interventions.

3.6.3. Reinforcement learning

Reinforcement learning (RL) subsumes biological and technical concepts for solving an abstract class of problems. For instance, a robot or computer program in any environment must necessitate an optimal behavioural strategy while perceiving only limited feedback from that environment (Bertsekas and Tsitsiklis, 1996; Sutton and Barto, 1998). RL aims to find a policy that maximizes the long-term reward. Compared to supervised learning, where training data provide information about the correct behaviour in particular situations, RL learning must be based on considerably less knowledge. It is rooted in the neuronal and behavioural sciences and recent results in computational neuroscience (Niv et al., 2005). It tries to bridge the gap between formal RL algorithms and biological substrates (Niv et al., 2005).

RL has been used successfully to address several challenging sequential decision-making problems in modern society LeCun et al. (2015). Together with DL techniques have become most useful in healthcare problems as well as policymaking and formulation processes. The combination of RL and supervised learning has been used successfully in addressing problems of high dimensional state space (Goodfellow et al., 2016; Schmidhuber, 2015). It has been noted that an artificial agent in the RL setup tries to search for an optimal policy for a given set of states to maximize long-term reward. RL has been successful in complicated tasks with lower prior knowledge thanks to its ability to learn different levels of abstractions from data (Mnih et al., 2015). For example, an RL agent can learn from visual perceptual inputs of thousands of pixels (Mnih et al., 2015). The branches of ML are highlighted in the diagram below **Figure 2**:

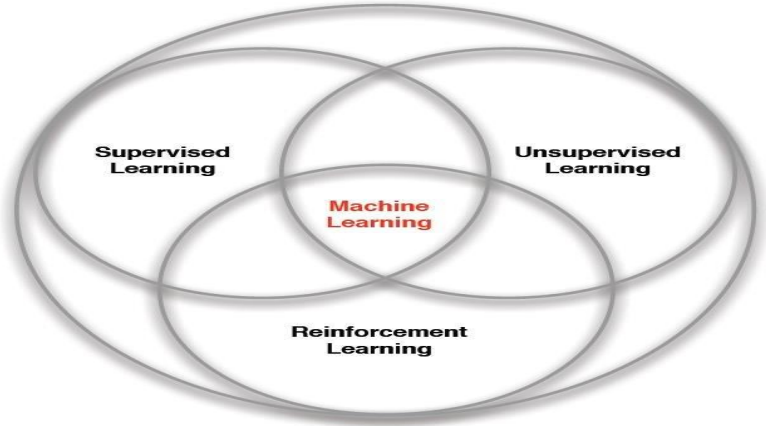

Figure 2. The Branches of Machine Learning.
Source: Silver (2016).

The use of ML in modern society to alleviate and address many problems that face humanity is also incredible and significant. Schapire (2008) highlighted that ML enables face detection and optical character detection. It helps detect faces in an image and sort out the images of handwritten characters apart from those that are not. ML has been found to detect fraud and fraudulent activities in several transactions, diagnosing different diseases of patients, and as well as spam detection in classifying emails which are spam or not respectively Schapire (2008). Moreover, ML has been found to understand spoken language by detecting words spoken and classifying them into a fixed set of categories. It has been found to enable weather prediction by assuring meteorologists whether it is going to be sunny, rainy, windy, or snowy Schapire (2008). ML has also been successfully used in customer segmentation to make predictions of which clients are going to respond well to information or not. ML has also been adopted in public and private sectors to trigger customers' orders and purchase a service from the service provider. In healthcare, ML would seek to have results that are as accurate as possible. Moreover, ML enables policymakers to resort to comparing similar policies abroad, performing policy trials, or developing statistical models that assist in predicting likely outcomes. In this capacity, ML predictive power allows policymakers to anticipate a policy's impact before implementing it, supporting policy adoption decisions. ML has successfully helped the public sector automate many highly labour-intensive data processing and analysis activities. This has thus increased the accuracy, efficiency, and speed of government services and actions.

3.6.4. Opacity of ML algorithmic technology in healthcare services

While ML algorithms enhance the decision-making capabilities of clinicians and healthcare institutions, they entail trade-offs at the epistemic and normative levels (Caroll et al., 2020). Applying ML algorithms to healthcare systems improves the accuracy of medical diagnosis and treatments; however, algorithms have been found to incur the expenses of opacity when trying to assess the reliability of a given diagnosis (Caroll et al., 2020). ML algorithms affect the transparency of medical treatments. This lack of transparency affects complex systems, such as EHR systems, for ordering, communicating, storing, and retrieving clinical information (Herzog, 2019). For instance, during the treatments of patients, clinical record data entry and record keeping, which order a patient's medications, can involve automated dosage

calculations (Herzog, 2019). This calculation may cause errors due to incorrect input, malfunctioning software or hardware, erroneous formulas, inconsistencies in medication recording, and difficulty in reading (or even finding) (Koppel et al., 2007). This would thus affect the medical diagnosis and treatment of patients, preventing the delivery of adequate health services that lead to good health and well-being.

Applying ML algorithms to healthcare without clear technological skills affects transparency, compromising patient health and safety (Kaplan, 2020, p. 3). Kaplan (2020, p. 3) also argued that "transparency, explainability, interpretability, testability, understandability, identifiability of inherent biases or outright errors, correctability, and accountability all are compromised." However, the above are mainly fundamental to accepting algorithmic recommendations in healthcare." ML algorithms can complicate understanding the resultant calculation, leading to errors that seriously harm patients (Kaplan, 2020, p. 3). Moreover, Herzog (2019) has argued that if humans train an algorithm, the nature and quality of that training and trainers may be unknown. Furthermore, applying ML algorithms, if not supervised and monitored by experts, may complicate assessing the underlying data (Cortez, 2017; Hoffman and Podgurski, 2013). Scholars have argued that it is difficult to know how and why an algorithm gives the results it does, resulting in a black box that leads to informational asymmetries (Braun et al.,2020; Grote and Berens, 2020). Moreover, how the ML algorithm works or gives the results is unknown to health professional workers and or patients affected by it (Herzog, 2019). That makes assessing the algorithm and associated ethical considerations, risks, and healthcare responsibilities complex and challenging (Braun et al., 2020; Grote and Berens, 2020).

Endo (2018, p. 838) argued that the application of ML algorithms in healthcare is essential, and yet, currently, there is a lack of understanding of the technology and the cost of hiring technological experts. In the context of Africa, a lack of sustainable financial resources to make use of ML algorithms technology would pose a challenge. Topol (2019, p. 49) also associates the lack of transparency in healthcare when using ML algorithm technology with the lack of health workers who are highly acquainted with the workings of the technology. Topol (2019, p. 50) argued that algorithmic opacity has led to the incorporation of transparency requirements. Burrell (2016, p. 6–7) identifies three forms: "(i) Opacity as intentional secrecy, (ii) opacity as technical illiteracy, and (iii) opacity from complexity as the mismatch between mathematical machine learning outputs and human ways of interpretation." Furthermore, the lack of technological skills in ML algorithms during the treatments of patients in clinical trials may lead doctors to refrain from questioning the validity of the computer models altogether and develop over-confidence in machine intelligence (Burrell, 2016; Hannun et al., 2019; Topol, 2019). Herzog (2019) argued that the distributed nature of medical data fusion and aggregation may further result in epistemic opacity, thus affecting the delivery of adequate health services. Moreover, financial constraints may intensify the early application of opaque ML algorithms solutions at risk and thus reduce life-saving accidental diagnoses (Herzog, 2019). This is because the system's focus may be too narrow and is promoted to work entirely without physician intervention (Herzog, 2019). Moreover, it has been noted that an ever more widespread use of automated medical data analysis could eventually force patients to consent to

data sharing (Char et al., 2018, p. 982). This violates the patient's right to privacy (Char et al., 2018, p. 982).

4. Discussions of the findings

The findings of this paper showed that delivering inadequate health services in South Africa has led to numerous social protests which has in turn affected the achievement of sustainable development. The paper found that ML is useful in medical data record keeping, therefore resolving the issues of poor record keeping that hinder the delivery of quality health services. This finding was in agreement with Niyitunga (2022a) who presented that medical data poses huge challenges to healthcare and has affected the delivery of adequate health services in Africa. The paper showed that the use of ML is set to keep and protect medical records from harm or damage, thus increase possibility of delivering quality health services. The paper also found that ML makes the data available when medical doctors and health workers need it to diagnose patients. Moreover, the paper findings showed that the use of ML enhances and improves clinical trial research, which has been a problem that has hindered the provision of quality health services in South Africa. ML uses sophisticated predictive analytics for clinical trial applicants and enables health workers and medical doctors to assess and evaluate a broader range of data, reducing the expenses and time required for medical tests (Javaid et al., 2022). The findings of this paper equally shoed that ML can improve clinical trial efficiency, and helped determine optimal sample sizes for greater efficacy and reduce the possibility of data errors using electronic health records. Toh and Brody (2021, p. 12) agreed that ML algorithms lessen the error gap and are near to accuracy because they use digital technologies of Convolutional Neural Networks (CNNs) to boost the image classifying performance.

The findings of this paper revealed that ML algorithms resolve the issues of the lack of well-trained radiologists that face healthcare systems in Africa. Niyitunga (2022b) agreed that blockchain technology can address the shortages of human resources that have hindered the timely delivery of quality health services. Moreover, ML offers individualized therapies that are more dynamic and efficient by combining personal health with predictive analytics (Siddique and Chow, 2021). ML boosts research and clinical trials to identify patients' previous doctor visits. ML ensures that medical records and data are accessed in real-time, manages the trial associates, and can correct the unstructured data in patient records, previous therapies, and the patient's family's medical history, thus providing quality health services to the patients. Using ML algorithms in healthcare enables medical practitioners to extract insights from historical data such as diseases, family history, and genetic diseases to make swift judgments that promote the delivery of quality health services (Durga et al., 2019).

Using ML algorithms in medical data records minimizes data-based errors (Manogaran and Lopez, 2017). The current clinical standard for diagnosing diseases is prone to human error as it depends on radiologists, pathologists, and physicians to examine the medical images and determine the underlying causes of diseases. In the medical field, the accuracy of diagnosis is extremely important, as a small error in the diagnosis can lead to severe consequences. It could, for example, lead to the wrong dosage or prescription of drugs as well as lead to surgery where none was needed and

vice-versa (Ibrahim and Abdulazeez, 2021). ML algorithms can analyse imaging data like a highly skilled radiologist can, detecting abnormal skin patches, lesions, tumours, and brain bleeding. As a result, the use of these platforms to aid radiologists is expected to skyrocket (Roth et al., 2018).

The findings showed that ML enables medical health workers to conduct medical treatments at a low cost and predict looming pandemics in a short time and predict looming pandemics. This means that ML can help strengthen the delivery of adequate healthcare services in South Africa, which is facing inadequate financial problems, thus achieve good health and well-being for realising sustainable development. ML algorithms in the healthcare sector enable medical doctors and health workers to use less time and assign a complete treatment to the patient, resulting in fewer expenses (Javaid et al., 2022). Moreover, the ML algorithm used in the healthcare sector assists medical doctors and health workers predict real health issues because it enables the evaluation of patients' history data (Rajendran et al., 2021). ML algorithm allows medical doctors and health workers to make timely and informed decisions about patient care and operational programs, thus saving millions of lives (Rahane et al., 2018). ML can produce algorithms that discover new scientific information that doctors cannot be able to predict just from imaging; this makes machine learning a potential new biomarker. Predictions like cardiovascular risk are detected in a non-invasive way, which gives the doctors a better percentage of success if surgery is needed.

Not only in South Africa, but also in Africa, there is a shortage of radiologists and other healthcare workers. ML enables medical imaging and interprets the results in a short time. The findings of this paper showed that ML used in the clinics and hospitals can detect preventable diseases like diabetic retinopathy, which is the fastest cause of blindness in South Africa. This is because there are not enough medical doctors and professionals who can offer this service to the millions of people suffering from diabetes in South Africa. For example, using ML technologies like Convolution Neural Network (CNN) that reads fundus images can detect whether one is likely to have begun this disease and act accordingly to prevent it. ML eases doctors' workload because doctors can quickly detect diseases with fast access to big data. Human resources in the healthcare industry are always in shortage because of the large world population; therefore, sometimes doctors operate daily in a robotic manner as it is always busy in the hospitals. However, ML helps them catch their breath and deliver healthcare services more empathetically. ML prevents biases in hospitals, which has prevented the achievement of quality health services. For example, ML is useful in the treatment of depression, hypertension, and diabetes. This is because these diseases need a unique treatment, which makes a medical doctor rely on their previous experience with this disease and assign the same treatment. ML, in this case, uses the complex data available on this patient's medical history and disease to train high-capacity models to provide unique treatment for the patient.

ML helps geocode data, epidemics and syndrome monitoring surveillance, medical imaging and predictive modeling, and decision support (Secinaro et al., 2021). ML is used to diagnose diseases; the most common method used is classification algorithms; this method deals with problems occurring at any point in everyday life. The classification algorithms build a model using the training data, and the final model

is used to test data to arrive at a prediction (Ibrahim and Abdulazeez, 2021). ML in the medical field is in medical images, for instance, computerized axial tomography (CAT) scans, magnetic resonance imaging (MRI), ultrasound (US) imaging, and positron emission tomography (PET) scans (Coursera, 2022). In this case, the ML techniques find images and predict which disease or the state of health in patients (Ibrahim and Abdulazeez, 2021).

The findings showed that ML promotes the policymaking process to improve governance in the healthcare sector. It was revealed that ML algorithms and DL can govern healthcare information and data to be truly owned by the patients themselves. This, therefore, addresses the challenges of poor governance for healthcare information that affects the provision of quality health services in Africa. ML algorithms promote the decision-making process and ease clinical decision processes regarding patients. This is because, numerous times, healthcare workers and professionals miss positive progress made toward a new treatment due to a lack of manpower to go through the repository of documents. Automated ML algorithms make this process easier; in terms of genetics large samples of human genomes are collected to evaluate various trends among the human population. ML helps in assessing the environment to prevent diseases; for example, external factors can affect a person's DNA and result in mutations (Toh and Brody, 2021). Knowing and governing this information reduces the chance of someone contracting diseases (Toh and Brody, 2021). This is where human security comes in because patients themselves would have the right to deny or accept who uses their information. It also encourages the empowerment of patients as only they have the power to govern and share their health records.

The findings of this paper showed that ML algorithms govern healthcare information and ensure quality management in healthcare systems. For instance, in Africa, achieving good health and well-being is hindered by the circulation of fake or counterfeited medical drugs, which are not only less effective but also harmful to the health of the patients. ML algorithms used in the healthcare sector can detect fake drugs on marketplaces and pharmaceuticals. It can detect the drugs' active ingredients and image sample composition. It relies on providing accurate information about the pharmaceutical manufacturers, product serial numbers, and package numbers on blockchain. This would ensure that even patients can confirm the drugs' authenticity by connecting to blockchain technology (Khezr et al., 2018). The primary benefit is that it has low-cost quality control and product registration, and drugs can easily be tracked Khezr et al. (2018).

The paper found that ML can be used alongside with Internet of Medical Things (IoMT) and blockchain technologies to remind patients of their appointments, detect changes in their blood pressure, how much calories they have burnt. They therefore ensure fast treatment and the correct specialised treatment for the patients. IoT is a smart technology that enables real-time monitoring and surveillance of patients, and together with blockchain can be used to execute critical health cases that increase mortality rates (Niyitunga, 2022b). Such a combination can also be used to evaluate the information collected by IoT healthcare smart devices based to promote quality treatment of patients and as well as data management. This solves the problem of logging the transfer of data in the IoT healthcare system Khezr et al. (2018). The

healthcare industry is overwhelmed with the ever-growing population and fewer trained medical professionals. ML can help to increase the productivity and precision of existing ones, more patients are treated in less time, as well as improve the outcomes of healthcare Jabbar et al. (2018). As health and human security are interconnected, this would enable the achievement of sustainable human security, thus leads to sustainable development.

The main issues in the healthcare system in South Africa's public health, are the information gap, incomplete data, and missed insights that could improve healthcare. The other issue is the decision gap; thus, patients' visits to the clinics for a medical check-up may be irregular, and however, decisions happen hourly, weekly, or daily. The findings of this paper showed that the use of ML in public healthcare solves these issues because if patients with diseases like diabetes are continuously monitored even if they leave the clinics to their homes. This would enable the achievement of sustainable human security, thus leads to sustainable development. The ML would introduce small machine learning devices that help monitor the blood pressure, glucose levels and indigestion of different foods. This would empower patients for example by giving them information on glucose levels so that they can know which levels are ideal and which ones are not, making patients be in a better place to make decisions based on this information.

ML reads and processes medical documents and physical medical records making the job harder for healthcare professionals as the process was slower, the hand-written documents which were sometimes difficult to read or incomplete information leading to poor management of patients (Coursera, 2022). The findings showed that ML applications to hospitals and clinics can be used in genetics to find the root causes of diseases or predict different illnesses. ML helps to provide accessibility to large amounts of data and next-generation sequencing techniques to explore how different genes are susceptible to diseases and, thus, how some genes can decrease or increase the risk of someone having a particular illness (Toh and Brody, 2021).

5. Conclusion

The paper sought to examine the role of ML algorithms in promoting good health and well-being for sustainable human security in Africa. The paper found that sustainable human security depends on providing adequate and quality health services. However, factors like inadequate finances, poor governance for healthcare, prolonged waiting time, shortage of human resources, and poor record keeping have hindered the provision of quality health services that lead to good health and well-being for sustainable human security. The paper presented that the above factors remained unaddressed and unresolved, thus preventing the delivery of health services to promote good health and well-being. The paper found that using ML algorithms makes the governance of medical records data possible and makes health information accessible in a short time. This therefore enables medical professionals and patients to communicate without difficulties. Patients can easily access useful information on illnesses without scheduling an appointment to be physically present. The quality of health services is of the highest level because doctors can easily check the patient's medical history and their family to detect the early onset of diseases and their

prevention. For example, all the audio biomarkers and images can easily detect diseases. This therefore improves medical treatment hence increasing the possibility of providing quality health services that promote good health and well-being for sustainable human security, and thus achieving sustainable development in South Africa. ML is used in healthcare premises was found to increase detection of critical diseases such as lesions in brain scans, mammograms, and other body scans. The use of ML was found significant as it determines whether the lesion is a lesion or other potential lesions and if it is malignant or benign, thus paving the way for the correct treatment of the patient. ML can digitalise old medical records by regularly scanning old typed and handwritten documents and creating a database system, thus keep and protect medical records which are needed for medical doctors to provide adequate health services to the patients. Therefore, the use of ML is timely and significant as it improves the delivery of health services to achieve good health and well-being thus achieving sustainable human security for sustainable development in South Africa.

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References

Aaker, D. A., Kumar, V., Day, G. S., et al. (2007). Marketing research, 2nd ed. Wiley, New York.

Adadi, A., & Berrada, M. (2018). Peeking Inside the Black-Box: A Survey on Explainable Artificial Intelligence (XAI). IEEE Access, 6, 52138–52160. https://doi.org/10.1109/access.2018.2870052

Akhil, J., Samreen, S., & Aluvalu, R. (2018). The Future of Health care: Machine Learning. International Journal of Engineering & Technology, 7(4.6), 23. https://doi.org/10.14419/ijet.v7i4.6.20226

Aldis, W. (2008). Health security as a public health concept: A critical analysis. Health Policy and Planning, 23(6), 369-75.

Aliper, A., Plis, S., Artemov, A., et al. (2016). Deep Learning Applications for Predicting Pharmacological Properties of Drugs and Drug Repurposing Using Transcriptomic Data. Molecular Pharmaceutics, 13(7), 2524–2530. https://doi.org/10.1021/acs.molpharmaceut.6b00248

Alpaydin, E. (2014). Introduction to Machine Learning. London: The MIT Press.

Angermueller, C., Pärnamaa, T., Parts, L., et al. (2020). Deep learning for computational biology. Molecular Systems Biology, 16(6), e9114.

Armour, S. (2008). Foreclosures take an emotional toll on many homeowners. Available online: https://www.ithappenedtous.com/articles/National_Articles/Foreclosures_take_an_emotional_toll.pdf (accessed on 3 May 2024).

Barron, P.; Padarath, A. (2017). Twenty years of the South African Health Review. South African Health Review.

Beck, M.; Dumpert, F. Feuerhake, J. "The Use of Machine Learning in Official Statistics. Available online: https://www.researchgate.net/publication/329945338_Machine_Learning_in_Official_Statistics. 2018 (accessed on 3 May 2024).

Becker, S., Kunze, C., & Vancea, M. (2017). Community energy and social entrepreneurship: Addressing purpose, organisation and embeddedness of renewable energy projects. Journal of Cleaner Production, 147, 25–36. https://doi.org/10.1016/j.jclepro.2017.01.048

Bertsekas, D. P., & Tsitsiklis, J. N. (1996). Neuro-Dynamic Programming. Athena Scientific. TheMIT Press, Cambridge, MA.

Bishop, C. M. (2006). Pattern recognition and machine learning. (Information Science andStatistics). Springer-Verlag New York, Inc.

Bliss, L. A. (2016). Phenomenological Research. International Journal of Adult Vocational Education and Technology, 7(3), 14–26. https://doi.org/10.4018/ijavet.2016070102

Braun, M., Hummel, P., Beck, S., et al. (2020). Primer on an ethics of AI-based decision support systems in the clinic. Journal of Medical Ethics, 47(12), e3–e3. https://doi.org/10.1136/medethics-2019-105860

Brewka, G. (1996). Artificial intelligence—a modern approach by Stuart Russell and Peter Norvig, Prentice Hall. Series in Artificial Intelligence, Englewood Cliffs, NJ. The Knowledge Engineering Review, 11(1), 78–79. https://doi.org/10.1017/s0269888900007724

Burns, N., & Grove, S. K. (2009). The Practice of Nursing Research: Appraisal, Synthesis, and Generation of Evidence, 6th ed. St. Louis, Mo: Saunders/Elsevier.

Burrell, J. (2016). How the machine 'thinks': Understanding opacity in machine learning algorithms. Big Data & Society, 3(1), 205395171562251. https://doi.org/10.1177/2053951715622512

Carroll, N., Richardson, I., & Abbas, R. (2020). "The Algorithm Will See You Now": Exploring the Implications of Algorithmic Decision-making in Connected Health. Proceedings of the 13th International Joint Conference on Biomedical Engineering Systems and Technologies, 758–765. https://doi.org/10.5220/0009178500002513

Caruana, R., Lou, Y., Gehrke, J., et al. (2015). Intelligible Models for HealthCare. Proceedings of the 21th ACM SIGKDD International Conference on Knowledge Discovery and Data Mining. https://doi.org/10.1145/2783258.2788613

Char, D. S., Shah, N. H., & Magnus, D. (2018). Implementing Machine Learning in Health Care — Addressing Ethical Challenges. New England Journal of Medicine, 378(11), 981–983. https://doi.org/10.1056/nejmp1714229

Chen, L. C., Leaning, J., Narasimhan, V. (edirors) (2003). Global health challenges for human security. Cambridge, MA: Harvard University Press.

Cieza, A. (2019). Rehabilitation the Health Strategy of the 21st Century, really? Archives of Physical Medicine and Rehabilitation, 100(11), 2212–2214. https://doi.org/10.1016/j.apmr.2019.05.019

Cortez, N. (2017). Substantiating Big Data in Health Care, 14 I/S: The Journal of Law, Ethics and Public Policy. 85.

Coursera, S. (2022). What is Machine Learning in Healthcare? Applications and Opportunities. Available online: https://www.coursera.org/gb/articles/machine-learning-in-health-care (accessed on 3 May 2024).

Delve, H., Limpaecher, A. (2022). What is qualitative Phenomenological Research Design? Essential Guide to Coding Qualitative Data.

Diakopoulos, N. (2016). Accountability in algorithmic decision making. Communications of the ACM, 59(2), 56–62. https://doi.org/10.1145/2844110

Durga, S., Nag, R., & Daniel, E. (2019). Survey on Machine Learning and Deep Learning Algorithms used in Internet of Things (IoT) Healthcare. 2019 3rd International Conference on Computing Methodologies and Communication (ICCMC), 1, 1018–1022. https://doi.org/10.1109/iccmc.2019.8819806

Dye, C, F., & Garman, A.N. (2015). Exceptional Leadership: 16 Critical Competencies for Healthcare Executives, Second Edition (ACHE Management). Health Administration Press.

Eggers, W. D., Schatsky, D., & Viechnicki, P. (2017). AI-augmented government: Using Cognitive technologies to redesign public sector work. Available online: https://www2.deloitte.com/us/en/insights/focus/cognitive-technologies/artificial-intelligence-government.html (accessed on 3 May 2024).

Endo, S. K. (2018). Technological Opacity & Procedural Injustice. Boston College Law Review, 59, 821-876.

European Commission. (2018). Communication from the commission to the European parliament, the European Council, the council, the European economic and social committee and the committee of the regions: Artificial Intelligence for Europe. Available online: https://ec.europa.eu/transparency/documentsregister/detail? (accessed on 3 May 2024).

Fischer, M., Heim, D., Hofmann, A., et al. (2020). A taxonomy and archetypes of smart services for smart living. Electronic Markets, 30(1), 131–149. https://doi.org/10.1007/s12525-019-00384-5

Fonn, S., Ray, S., & Blaauw, D. (2011). Innovation to improve health care provision and health systems in sub-Saharan Africa – Promoting agency in mid-level workers and district managers. Global Public Health, 6(6), 657–668. https://doi.org/10.1080/17441692.2010.489905

Goodfellow, I., Bengio, Y., & Courville, A. (2016). Deep Learning. The MIT Press.

Google Developers. (2019). Bringing AI and machine learning innovations to healthcare. Available online: https://youyu.be/JzB7yS9t1YE. (Accessed on 27 February 2023).

Grote, T., & Berens, P. (2019). On the ethics of algorithmic decision-making in healthcare. Journal of Medical Ethics, 46(3), 205–211. https://doi.org/10.1136/medethics-2019-105586

Gutlove, P., & Thompson, G. (2003). Human security: Expanding the scope of public health. Medicine, Conflict and Survival, 19(1), 17–34. https://doi.org/10.1080/13623690308409661

Hannun, A. Y., Rajpurkar, P., Haghpanahi, M., et al. (2019). Cardiologist-level arrhythmia detection and classification in ambulatory electrocardiograms using a deep neural network. Nature Medicine, 25(1), 65–69. https://doi.org/10.1038/s41591-018-0268-3

Herzog, C. (2019). Technological Opacity of Machine Learning in Healthcare. Available online: https://www.weizenbaum-library.de/server/api/core/bitstreams/880c25ac-0db6-41af-a441-4283f2895663/content (accessed on 3 May 2024).

Hoffman, S., & Podgurski, A. (2013). The Use and Misuse of Biomedical Data: Is Bigger Really Better? American Journal of Law & Medicine, 39(4), 497–538. https://doi.org/10.1177/009885881303900401

Holt, M. (2018). Artificial Intelligence in Modern Society. Integrated Studies. 138.

Homan, M. S. (2008). Promoting community change: Making it happen in the real world. Belmont, CA: Brooks/Cole-Wadsworth/Thompson.

Ibrahim, I., & Abdulazeez, A. (2021). The Role of Machine Learning Algorithms for Diagnosing Diseases. Journal of Applied Science and Technology Trends, 2(01), 10–19. https://doi.org/10.38094/jastt20179

Institute of Medicine. (1992). Emerging Infections: Microbial Threats to Health in the United States. Washington Dc: National Academy Press.

Institute of Medicine. (1997). America's Vital Interest in Global Health: Protecting Our People, Enhancing Our Economy and Advancing Our International Interests. Washington Dc: National Academies Press.

Jaitman, L., Soares, R., Olavarría-Gambi, M., et al. (2015). The Welfare Costs of Crime and Violence in Latin America and the Caribbean. Inter-American Development Bank. https://doi.org/10.18235/0000170

Javaid, M., Haleem, A., Pratap Singh, R., et al. (2022). Significance of machine learning in healthcare: Features, pillars and applications. International Journal of Intelligent Networks, 3, 58–73. https://doi.org/10.1016/j.ijin.2022.05.002

Jayanth Balaji, A., Harish Ram, D. S., & Nair, B. B. (2018). Applicability of Deep Learning Models for Stock Price Forecasting an Empirical Study on BANKEX Data. Procedia Computer Science, 143, 947–953. https://doi.org/10.1016/j.procs.2018.10.340

Jordan, M. I., & Mitchell, T. M. (2015). Machine learning: Trends, perspectives, and prospects. Science, 349(6245), 255–260. https://doi.org/10.1126/science.aaa8415

Kama, Z. S. (2017). An evaluation of access to health care: Gugulethu Community Health Clinic. Available online: https://www.semanticscholar.org/paper/An-evaluation-of-access-to-health-care-%3A-Gugulethu-Kama/5a28e37f77cd8836f90e591eb2d3c5cc56fc5d19 (accessed on 3 May 2024).

Kaplan, B. (2020). Seeing Through Health Information Technology: The Need for Transparency in Software, Algorithms, Data Privacy, and Regulation. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.3672395

Kharb, L., & Singh, P. (2021). Role of Machine Learning in Modern Education and Teaching. Impact of AI Technologies on Teaching, Learning, and Research in Higher Education, 99–123. https://doi.org/10.4018/978-1-7998-4763-2.ch006

Khezr, S., Moniruzzaman, M., Yassine, A., et al. (2019). Blockchain Technology in Healthcare: A Comprehensive Review and Directions for Future Research. Applied Sciences, 9(9), 1736. https://doi.org/10.3390/app9091736

Kinnear, T. C., & Taylor, J. R. (1996). Marketing Research: An Applied Approach. McGraw-Hill.

Kirigia, J. M., & Wambebe, C. (2006). Status of national health research systems in ten countries of the WHO African Region. BMC Health Services Research, 6(1). https://doi.org/10.1186/1472-6963-6-135

Kirigia, J. M., Asbu, E. Z., Greene, W., et al. (2007). Technical Efficiency, Efficiency Change, Technical Progress and Productivity Growth in the National Health Systems of Continental African Countries. Eastern Africa Social Science Research Review, 23(2), 19–40. https://doi.org/10.1353/eas.2007.0008

Koelble, T. A., & Siddle, A. (2013). Institutional complexity and unanticipated consequences: the failure of decentralization in South Africa. Democratization, 21(6), 1117–1133. https://doi.org/10.1080/13510347.2013.784270

Kononenko, I. (2001). Machine learning for medical diagnosis: history, state of the art, and perspective. Artificial Intelligence in Medicine. 23(1):89-109. https://doi.org/10.1016/s0933-3657(01)00077-x

Koppel, R. (2005). Role of Computerized Physician Order Entry Systems in Facilitating Medication Errors. JAMA, 293(10), 1197. https://doi.org/10.1001/jama.293.10.1197

Längkvist, M., Karlsson, L., & Loutfi, A. (2014). A review of unsupervised feature learning and deep learning for time-series modeling. Pattern Recognition Letters, 42, 11–24. https://doi.org/10.1016/j.patrec.2014.01.008

LeCun, Y., Bengio, Y., & Hinton, G. (2015). Deep learning. Nature, 521(7553), 436–444. https://doi.org/10.1038/nature14539

Libbrecht, M. W., & Noble, W. S. (2015). Machine learning applications in genetics and genomics. Nature Reviews Genetics, 16(6), 321–332. https://doi.org/10.1038/nrg3920

Manogaran, G., & Lopez, D. (2017). A survey of big data architectures and machine learning algorithms in healthcare. International Journal of Biomedical Engineering and Technology, 25(2/3/4), 182. https://doi.org/10.1504/ijbet.2017.087722

Mantri, S., Lawson, J. M., Wang, Z., et al. (2020). Identifying Moral Injury in Healthcare Professionals: The Moral Injury Symptom Scale-HP. Journal of Religion and Health, 59(5), 2323–2340. https://doi.org/10.1007/s10943-020-01065-w

Marais, D. L., & Petersen, I. (2015). Health system governance to support integrated mental health care in South Africa: challenges and opportunities. International Journal of Mental Health Systems, 9(1). https://doi.org/10.1186/s13033-015-0004-z

Miller, G., Pinto, D., & Vera-Hernández, M. (2013). Risk Protection, Service Use, and Health Outcomes under Colombia's Health Insurance Program for the Poor. American Economic Journal: Applied Economics, 5(4), 61–91. https://doi.org/10.1257/app.5.4.61

Mitchell, T.M. (1997). Machine Learning. McGraw-Hill, Inc., New York.

Mnih, V., Kavukcuoglu, K., Silver, D., et al. (2015). Human-level control through deep reinforcement learning. Nature, 518, 529-533.

Mosadeghrad, A., & Ferdosi, M. (2013). Leadership, Job Satisfaction and Organizational Commitment in Healthcare Sector: Proposing and Testing a Model. Materia Socio Medica, 25(2), 121. https://doi.org/10.5455/msm.2013.25.121-126

Niv, Y., Duff, M. O., & Dayan, P. (2005). Dopamine, uncertainty and TD learning. Behavioral and Brain Functions, 1(1). https://doi.org/10.1186/1744-9081-1-6

Niyitunga, E. B. (2022). Current and potential role of blockchain-based technology in managing medical records in Africa. Digital Policy Studies, 1(1), 52–68. https://doi.org/10.36615/dps.v1i1.1253

Niyitunga, E. B. (2022a). Good Health-Sustainable Development Nexus: Assessing the Prospects and Opportunities of Artificial Intelligence in Africa. African Journal of Governance and Development, 11(1.1), 47-78.

Obermeyer, Z., & Emanuel, E. J. (2016). Predicting the Future — Big Data, Machine Learning, and Clinical Medicine. New England Journal of Medicine, 375(13), 1216–1219. https://doi.org/10.1056/nejmp1606181

Oleribe, O. E., Momoh, J., Uzochukwu, B. S., et al. (2019). Identifying Key Challenges Facing Healthcare Systems In Africa And Potential Solutions. International Journal of General Medicine, Volume 12, 395–403. https://doi.org/10.2147/ijgm.s223882

Oleribe, O. O., Ezieme, I. P., Oladipo, O., et al. (2016). Industrial action by healthcare workers in Nigeria in 2013–2015: an inquiry into causes, consequences and control—a cross-sectional descriptive study. Human Resources for Health, 14(1). https://doi.org/10.1186/s12960-016-0142-7

Omaswa, F. (2014). Solutions for Africa's Health Workforce Crisis through Country Based Research. Human Resources for Health, 12(S1). https://doi.org/10.1186/1478-4491-12-s1-i1

Pasquale, F. (2015). The Black Box Society. Available online: https://www.degruyter.com/document/doi/10.4159/harvard.9780674736061/html (accessed on 3 May 2024).

Perkins, D. D., & Zimmerman, M. A. (1995). Empowerment theory, research, and application. American Journal of Community Psychology, 23(5), 569–579. Portico. https://doi.org/10.1007/bf02506982

Petersen, I., Marais, D., Abdulmalik, J., et al. (2017). Strengthening mental health system governance in six low- and middle-income countries in Africa and South Asia: challenges, needs and potential strategies. Health Policy and Planning, 32(5), 699–709. https://doi.org/10.1093/heapol/czx014

Pigg, K. E. (2002). Three Faces of Empowerment: Expanding the Theory of Empowerment in Community Development. Journal of the Community Development Society, 33(1), 107–123. https://doi.org/10.1080/15575330209490145

Rahane, W., Dalvi, H., Magar, Y., et al. (2018). Lung Cancer Detection Using Image Processing and Machine Learning HealthCare. In: Proceedings of the 2018 International Conference on Current Trends towards Converging Technologies (ICCTCT). https://doi.org/10.1109/icctct.2018.8551008

Rajendran, S., Mathivanan, S. K., Jayagopal, P., et al. (2021). Emphasizing privacy and security of edge intelligence with machine learning for healthcare. International Journal of Intelligent Computing and Cybernetics, 15(1), 92–109. https://doi.org/10.1108/ijicc-05-2021-0099

Rajkomar, A., Oren, E., Chen, K., et al. (2018). Scalable and accurate deep learning with electronic health records. Npj Digital Medicine, 1(1). https://doi.org/10.1038/s41746-018-0029-1

Roff, H.M. (2017). Advancing human security through artificial intelligence. London: Chatham House.

Roncarolo, F., Boivin, A., Denis, J. L., et al. (2017). What do we know about the needs and challenges of health systems? A scoping review of the international literature. BMC Health Services Research, 17(1), 1-18.

Roth, J. A., Battegay, M., Juchler, F., et al. (2018). Introduction to Machine Learning in Digital Healthcare Epidemiology. Infection Control & Hospital Epidemiology, 39(12), 1457–1462. https://doi.org/10.1017/ice.2018.265

Samuel, A. L. (1959). Some Studies in Machine Learning Using the Game of Checkers. IBM Journal of Research and Development, 3(3), 210–229. https://doi.org/10.1147/rd.33.0210

Schapire, R. (2008). What is machine learning? Available online: https://www.cs.princeton.edu/courses/archive/spr08/cos511/scribe_notes/0204.pdf (accessed on 3 May 2024).

Schmidhuber, J. (2015). DL in neural networks: An overview. Neural Networks, 61.

Secinaro, S., Calandra, D., Secinaro, A., et al. (2021). The role of artificial intelligence in healthcare: a structured literature review. BMC Medical Informatics and Decision Making, 21(1). https://doi.org/10.1186/s12911-021-01488-9

Shickel, B., Tighe, P. J., Bihorac, A., et al. (2018). Deep EHR: A Survey of Recent Advances in Deep Learning Techniques for Electronic Health Record (EHR) Analysis. IEEE Journal of Biomedical and Health Informatics, 22(5), 1589–1604. https://doi.org/10.1109/jbhi.2017.2767063

Shrestha, Y. R., Krishna, V., & von Krogh, G. (2021). Augmenting organizational decision-making with deep learning algorithms: Principles, promises, and challenges. Journal of Business Research, 123, 588–603. https://doi.org/10.1016/j.jbusres.2020.09.068

Siddique, S., & Chow, J. C. L. (2021). Machine Learning in Healthcare Communication. Encyclopedia, 1(1), 220–239. https://doi.org/10.3390/encyclopedia1010021

Silver, D. (2016). The Fifth International Conference on Machine Learning (Report). Available online: https://www.researchgate.net/publication/220604958_The_Fifth_International_Conference_on_Machine_Learning_Report (accessed on 3 May 2024).

Sousa, W. G., de, Melo, E. R. P., de, Bermejo, P. H. D. S., et al. (2019). How and where is artificial intelligence in the public sector going? A literature review and research agenda. Government Information Quarterly, 36(4), 101392. https://doi.org/10.1016/j.giq.2019.07.004

Stoeva, P. (2020). Dimensions of Health Security—A Conceptual Analysis. Global Challenges, 4(10). Portico. https://doi.org/10.1002/gch2.201700003

Streubert, H. J., Carpenter, D. R. (2002). Qualitative research in nursing: Advancing the humanistic imperative. Philadelphia: Lippincott Williams & Wilkins.

Sun, T. Q., & Medaglia, R. (2019). Mapping the challenges of Artificial Intelligence in the public sector: Evidence from public healthcare. Government Information Quarterly, 36(2), 368–383. https://doi.org/10.1016/j.giq.2018.09.008

Sutton, R. S., & Barto, A. G. (1998). Reinforcement Learning: An Introduction. IEEE Transactions on Neural Networks, 9(5), 1054–1054. https://doi.org/10.1109/tnn.1998.712192

Tana, V. V. (2013). Experiences of chronic patients about long waiting time at a community health care center in the Western Cape. Available online: https://scholar.sun.ac.za/items/f05aab42-5f59-41ee-aa7f-fc0ff3f41366 (accessed on 3 May 2024).

The White House. (1994). A National Security Strategy for Engagement and Enlargement. Available online: http://history.defense.gov/Portals/70/Documents/nss/nss1994.pdf?ver=2014-06-25-121219-500 (accessed on 3 May 2024).

Toh, C., & P. Brody, J. (2021). Applications of Machine Learning in Healthcare. Smart Manufacturing - When Artificial Intelligence Meets the Internet of Things. https://doi.org/10.5772/intechopen.92297

Topol, E. J. (2019). High-performance medicine: the convergence of human and artificial intelligence. Nature Medicine, 25(1), 44–56. https://doi.org/10.1038/s41591-018-0300-7

Visser, R., Bhana, R. and Monticelli, F. (2012) The National Health Care Facilities Baseline Audit National Summary Report. HST, Durban.

Winton, R., Larrubia, E., & Yoshino, K. (2008). Jobless man kills family, self. Available online: http://www.latimes.com/news/local/la-me-porterranch7-2008oct07,0,7425239.story (accessed on 17 May 2023).

World Health Organisation. (2007). Everybody's Business: Strengthening Health Systems to Improve Health Outcomes. Available online: https://www.who.int/publications/i/item/everybody-s-business----strengthening-health-systems-to-improve-health-outcomes (accessed on 3 May 2024).

World Health Organisation. (2013). WHO Global Health Expenditure Database. Available online: https://apps.who.int/nha/database (accessed on 17 May 2023).

Yin, R. K., (1994). Case Study Research Design and Methods: Applied Social Research and Methods Series, 2nd ed. Thousand Oaks, CA: Sage.

Zuiderwijk, A., Yu-Che, C., & Fadi, S. (2021). Implications of the Use of Artificial Intelligence in Public Governance: A Systematic Literature Review and a Research Agenda. Available online: https://ssrn.com/abstract=3813865 (accessed on 17 May 2023).