

The Application of Open Source Artificial Intelligence as an Approach to Frugal Innovation in Tanzania

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Abstract: - Due to the fact that Tanzania is considered a developing country with several challenges including the predominant problem of poverty, it can rely on open access artificial intelligence for frugal innovation. For this reason, this study explores the potential of applying open access artificial intelligences to promote frugal innovation in Tanzania. A content analysis was conducted to explore the initiatives for the implementation by government, private sector and higher learning institutions. The analysis revealed that government has no policies, funding, strategic plan or allocation for the implementation of open access AI in Tanzania. However, the private sectors have policies, funding allocation, strategic plan and non-financial resources for AI initiatives in Tanzania. Likewise, higher learning institutions like University of Dodoma have policies and funding allocation for AI implementation in Tanzania. Based on the findings, it is recommended for the government to formulate policies and dedicate financial and non-financial resources into open source AI technology as an approach to frugal innovation in Tanzania.

Keywords: Artificial intelligence, frugal innovation, open source, Tanzania

I. INTRODUCTION

The significance of artificial intelligence as a tool to propel human development is a hot topic today. Artificial technology has been applied in different field in sciences and arts. At the same time, artificial technology has advanced from solving simple issues to complex issues in both human life and other aspects as well. Furthermore, in the dawn of the 21st century, artificial intelligence is considered to cause another industrial revaluation in all aspects of human life (Bhattacharya, 2018). In this case, artificial technology is important are to explore especially in developing countries (Guibao, Yubo & Jialiang, 2018).

In developed countries, artificial intelligence has experienced rapid advancements that permeate every facet of human life and interactions. According to Frank, Autos, Bessen, Brynjolfsson, Cebrian, Deming, Feldman, Groh, Lobo, Moro, Wang, Youn & Rahwan (2019) artificial intelligence has a tremendous impact on the human capital and all issues to the development and progress of human kind. In North American countries like the US and Canada, Artificial intelligence has been used to provide medical appliance for human bodies like

limbs and organs. In additions, artificial intelligence has been applied to advance medical breakthroughs in complicated areas of health and human well being. Specifically, International research institute CIFAR is leading the government's Pan-Canadian artificial intelligence strategy with three new AI institutes: the Alberta Intelligence Institute of Edmonton, the vector institute of Toronto, and MILA in Montreal where by these three cities are leading centers for AI in CANADA (Kamble & Shah, 2018). Consequently, the effects of artificial intelligence have been modeled to solve the prevailing problems and challenges in the developed world.

From a European standpoint, European Union (EU) member states have declared their intention to collaborate on artificial intelligence to enhance their competitive advantages so as to tackle social, economic, ethical and legal issues and their implications. To make their intention into fruition, the European Union have allocated a total of \$ 24 billion to be invested in Artificial intelligence research by 2020 (Otani, Toube, Kimura & Furutani, 2018). More so, a number of European countries have spearheaded national initiatives to implement artificial intelligence to every possible facet of human lives. One of those countries is France which has commissioned to double the number of researcher focused on artificial intelligence projects. The French government has devoted approximately \$1.85 billion to fund research and start-ups in Artificial intelligence (Ramamoorthy & Yampolskiy, 2018). Concomitantly, the United Kingdom has established a comprehensive strategic plan to invest in Artificial intelligence and it is at the forefront of Artificial intelligence ethics (Samek, Wiegand, & Muller, 2018).

Asians countries have been taking artificial initiatives as well. For instance, the government of South Korea organized a presidential fourth industrial revolution committee in 2017 and declared a total investment of \$2 billion by 2022 to develop capabilities in AI research and development (Shabbir & Anwer, 2018). Similarly, Singapore has launched an AI national initiative to promote AI capacities through government institutions (Virginia, 2018). All these are efforts to advance artificial intelligence to meet their social and economic goals in the long run.

Emerging economies have not been left behind in artificial technologies. Countries such as China and India are leading the way in artificial technologies. These economies have realized the essence to the application of artificial technologies in propelling their countries forward in human development. Specifically, countries like China have been investing billions of dollars in artificial technologies in efforts to improve all sectors especially health care. The government of China is prioritizing artificial technology in its 13th five year plan (2016-2020) and as a result created a domestic AI market of 150 billion by 2020 and become a world-leading center by 2030 (Guibao, Yubo, & Jialiang, 2018). Likewise, the private sectors are also making significant strides in artificial intelligence to increase business efficiencies and productivities. Companies such as Alibaba, Baidu and Tencent as well as iFlytek are developing artificial intelligence in areas like autonomous vehicles, smart cities and medical imaging Otani, Toube, Kimura, & Furutani, 2018).

Like in developed and emerging economies, artificial intelligence can be applied to fill the gap in developing nations like Africa countries. Due to the fact that most of the African countries are confronted with a number of challenges, it is imperative for African countries to develop artificial intelligence capacity to tackle their underlying problems and challenges. In this scenario, countries such as South Africa, Nigeria and Kenya have been leading the way in Sub-Saharan Africa. In connection to this, developing nations especially in the African Continent are slower than other parts of the world to embrace technologies such as artificial intelligence and other developments. In this case, extreme poverty and a multitude of challenges have forced most of the African countries to lag behind in innovations in artificial intelligences (Mirondo, 2019). Given the lack of adequate resources, it is important for African countries to embark on frugal innovation in open access artificial intelligence so as to meet solves their problems and challenges (Mtambalike, 2019).

Due to the fact that Tanzania is considered a developing country with several challenges including the predominant problem of poverty, it can rely on frugal innovation in open access artificial intelligence (Isagah, 2019). Frugal innovation is a design innovative process in which the needs and the circumstances of citizens in the developing world are put first in order to develop appropriate adaptable, affordable and accessible services and products for emerging markets. In other words, frugal innovation involves developing innovative products and services to meet consumer needs with relatively low costs. In this case, open access artificial intelligence allows everyone to access artificial intelligence software for further improvement with the sole objective to meet specific demands or needs (Isagah, 2019). As a result, open access artificial technologies can be applied as frugal innovation to solve the problems and challenges in Tanzania (Mirondo, 2019). For this reason, this study explores the potential of applying open access artificial intelligences to promote frugal innovation in Tanzania.

Problem Statement

Disruptive technologies such as a AI pose several challenges in the developing world. This is due to the fact that most of the countries have not managed to tap into these potential resources. Some of the basic challenges are economic and social inclusion. The economic challenges in most the developing countries like Tanzania have not adequately taken initiatives to implement AI systems in solving their day to day problems (Isagah, 2019; . At the same time, most of the countries like Tanzania lack the infrastructure to apply AI in solving problems (Mtambalike, 2019). Furthermore, these countries do not have adequate and skills human capital with enough knowledge, experience, skills and expertise to use AI to solve their challenges and problems (Isagah, 2019; Mtambalike, 2019). In light of these problems and challenges, it is difficult for Tanzania to innovate and stay ahead of emerging technologies. In this case, it is important to reevaluate the initiatives taken by the government, private sector and higher learning institutions to promote open source AI technology as a means for frugal innovations in Tanzania.

Research Objectives

The following are the research objectives of this study

1. To identify the government initiatives in the implementation of artificial intelligence for frugal innovation in Tanzania.
2. To determine the private sector initiatives in the implementation of artificial intelligence for frugal innovation in Tanzania.
3. To examine the higher learning institutions initiatives in the implementation of artificial intelligence to promote frugal innovation among students in Tanzania

Research Questions

The following are the research questions of this study

1. What are the government initiatives in the implementation of Artificial Intelligence for Frugal Innovation in Tanzania?
2. What are the private sectors initiatives in the implementation of artificial intelligence for frugal innovation in Tanzania?
3. What are the higher learning institutions initiatives in artificial intelligence to promote frugal innovation among students in Tanzania?

II. LITERATURE REVIEW

The literature review provides a comprehensive discussion of related review of artificial intelligence. At the same time, this section provides the concept of frugal innovation in application of artificial intelligence. Furthermore, there is an in-depth discussion of theories, concepts and models of artificial intelligence in relation to frugal innovation. Most importantly, this section will explore empirical studies about

artificial intelligences especially in developing countries like Tanzania.

Theoretical Literature Review

The term artificial intelligence traces its origin in 1956. However, the artificial intelligence has gained popularity due to data volumes, advanced algorithms and improvement in computing power and storage (Virginia, 2018). This early work paved way for the automation and formal reasoning we see in computing capabilities in this era. This computing capability includes decision support systems and smart search systems that can be designed and programmed to execute and supplement human intelligence capabilities Shabbir & Anwer, 2018).

Given the origins and brief historical background of artificial intelligence, it is appropriate to define the terminology. Artificial intelligence is the simulation of human intelligence into computers or automated machines to function and perform as a human being. In other words, Artificial intelligence refers to the ability of a machine or computer to learn and eventually solve problems or make decisions based on the learning Samek, Wiegand & Muller, 2018).

Other consider artificial intelligence as a branch of computer science concerned with designing and building smart machines capable of performing several tasks and ultimately improving their capability through deep learning to enhance decision making (Ramamoorthy, A. & Yampolskiy, 2018). In this scenario, the ideal characteristic of artificial intelligence is its capabilities to reason and make appropriate decisions which the best possible chance of attaining a particular predetermined goal or objective.

There are several categories of artificial intelligences. These categories can be subdivided into two forms. The first category is weak artificial intelligence and strong artificial intelligence. Weak artificial intelligence refers to a system designed to perform one specific task (Otani, Toubé, Kimura & Furutani, 2018). A good illustration is video games such as playing chess. Strong artificial intelligence refers to a system which performs task like a human being. These tasks are more complex and complicated in nature (Mialhe & Hodes, 2017). These tasks involve solving complex problems without human intervention. A good example is self-driving vehicles with autonomous driving capabilities.

Importance of Artificial Intelligence

Artificial intelligence is at the forefront of the industrial revolution. This is because artificial intelligence revolutionizes the way in which business organizations in different spectrum compete and expand across the world by creating new products and services (Kamble & Shah, 2018). But at the same time, artificial intelligence increase production and operational efficiencies and as a result drives the overall business profitability and bottom-line (Guibao, Yubo & Jialiang, 2018).

Artificial intelligence makes it possible for automated machines to learn from different or multiple experiences and as a result adjusts to new inputs and therefore produces new desirable outcomes. Specifically, most of the artificial intelligence relies on deep learning and natural language processing to gain mastery in a specific field (Frank et al, 2019). For example, computer games and chess playing computers have gain exemplary mastery of the games and therefore they have been able to adapt to different setting and changes. Likewise for automated vehicles, artificial intelligence has taken some intelligence aspect of humans. In Reliance on artificial intelligence, computer of automated machinery can be learn to accomplish specific activities by processing multiple amounts of data and analyzing the patterns in the data (Bas, 2016).

Artificial intelligence has an integral part in the advances made in the contemporary world. Artificial intelligence makes machines or computers develop intelligence like human to performance several tasks (Bhattacharya, 2018). In this matter, machines are able to perform simple to complex activities that human needs to do on a regular basis. Artificial intelligence has improved the overall life and living standards of human being and promises to perform a lot more activities in the future (Kamble & Shah, 2018).

Revolution of Artificial Intelligence

There is tremendous advancement in artificial intelligence. These advancements have revolutionized the competitive advantage of industries, companies and productivity. As a result, IA has reshaped and restructured activities in various sectors which has spurred economic development of nations. In a number of several years, there has been multiple innovations and creativity results in health, robotics, computing technology and even automation of various sectors (Kamble & Shah, 2018). Moreover, artificial intelligence has been a driving force in creating new products and services. For instance, the advancement of AI propagated the development of facial recognition technologies and biomedical equipments (Frank et al, 2019). These advancements have been a result of several reasons.

The first reason is improvement in computing power and capacity. Specifically, there have been milestone improvements from central processing units to graphic processing units. Currently, Graphic processing units can perform 40 to 80 times faster compared to previous versions (Guibao, Yubo & Jialiang, 2018). These developments have prompted earlier developers to benefit from significant breakthroughs in artificial intelligence technologies. Companies such as Google are advancing further in creating sensor processing units. At the same time, there are a number of companies who are developing new and modern capacities in artificial intelligence. At another level, cloud solution provides cost effective alternatives computing and storage services Samek, Wiegand, & Muller, 2018). In connection to this, Microsoft is offering hybrid solutions through the combination of private and public cloud that assists businesses

to consolidate computing capabilities and therefore hold additional cloud requirements without extra capital outlays (Otani, Toubé, Kimura, & Furutani, 2018).

The second reason is explosion in data. The increase in economic activities has resulted into unprecedented amounts of data to be processed daily. This data feeds algorithms of raw material required to provide new insights. According to the international data corporation, it projects that there might be 163 Zettabytes (one trillion gigabytes) of data by 2025 or even ten times the generated data by 2016 (Mialhe & Hodes, 2017). The large amount of data generated implies that organizing and analyzing data is a daunting and challenging activity. Furthermore, there is opportunity to extract value from data that were not available in the past (Guibao, Yubo, & Jialiang, 2018).

The third reason is advancement in algorithms. The advancement in computation algorithms has improved artificial intelligence. Consequently, modern advancement in deep learning has increased computation accuracy of classification and predictions (Frank et al, 2019). Deep learning applies large number of neural networks use convolutional and recurrent neural networks (Bhattacharya, 2018). In this case, a computer can use deep learning to learn through data training and back propagation algorithms. One important aspect of learning is Meta-learning techniques. Meta-learning techniques has the sole purpose to automate the machine learning models and neural networks through reclassification of images in the large scale data sets (Kamble & Shah, 2018).. The same machine learning model is critical for the developing reinforcement learning. In this setting, it is a technique that permits algorithms to learn tasks through trial and errors and improve their performance based on repetition and experience (Guibao, Yubo, & Jialiang, 2018).

The Technical limitations of leveraging Artificial Intelligence in Frugal Innovation

Although artificial technology has gained prominence in the recent years as a tool to improve productivity and increase efficiency among industries, AI is still hindered by several technical factors which inevitably limit the application of AI in Frugal innovation (Bas, 2016).

There is a limitation of labeled training data. In artificial intelligence learning, machines cannot learn by themselves and therefore they required to be taught. This implies that human must label and categorize the prevalent training data. However, new technologies and modern techniques are devised to minimize the time spent on such activities, involving reinforcement learning and in-stream supervision such as generative adversarial networks, a monitored learning strategy which two network compete to improve their comprehension of a basic concept (Hossain, 2018).

The difficulty in obtaining adequate and appropriate large data sets might be another hindrance of artificial intelligence in frugal innovation (Vadakepat, Garg, Loh, & Tham, 2015). In other words, it might be difficult to acquire data sets to

train algorithms. For instance, the limited number of recorded data in developing countries like Tanzania might be a significant challenges confronting Artificial intelligence. This is just a single example among many sectors which is relatively difficult to acquire and generate adequate data set for deep learning. Alternatively, one strategy that would minimize the requirement for large data set is single-shot learning. Single-shot learning requires an AI model to be pre-trained in set of related data and eventually learn from a small number of real-life experiences (Weyrauch & Herstatt, 2016).

Another limitation in the application of AI in frugal innovation is the difficulty in results explanation. It is usually difficult to describe the results from complicate and large neural network based systems. To solve this issue, a development at an initial stage that would improve the easiness of explaining or transparency of models is local interpretable model agnostic explanations, which attempt to identify which parts of input data a trained model relies on most to make predictions (ITU, 2016; Shabbir & Anwer, 2018)). Another strategy that is gaining traction is the applying generalized additive models. These apply a single-featured model which limit interactions between features and enables users to interpret each one more appropriately (Bas, 2016).

The difficulty of generalization is a prevalent obstacle to AI in frugal innovation. It is relatively difficult for an AI model to transfer their experience from one set of situation to another (Virginia, 2018). Henceforth, businesses have to commit resources in new training for every case even though they share some similarities. For this situation, it is appropriate to apply transfer learning where by an AI model is training to apply learning from one activity to the next activity (Ramamoorthy & Yampolskiy, 2018).

The last limitation is risk of bias has raised several concerns and as a result might be challenging to solve. In this scenario, a number of reputable institutions and private researchers are devoting immense resources to solve biasness in artificial intelligence models (Samek, Wiegand & Muller, 2018).

The Application of Open source Artificial Intelligence in Frugal Innovation

In the age of consumerism and increased consumptions in both developed and developing countries, it is important to create goods and services at a relatively low cost. This is to increase the base of consumers in the lower income class. Concurrently, it is imperative to encourage innovation to improve the living standards of low income earners especially in developing countries like Tanzania (Hyvvarinen, Keskinen & Varis, 2016). In light of the rise of consumerism and innovation to meet the needs and expectations of developing nations, frugal innovation might be the answer to deal with those rising demands.

Experts define frugal innovation or frugal engineering as the process of reducing the complexity and cost of goods and its production (Mirondo, 2019). From another perspective, Bas

(2016) defines frugal innovation as a design of innovation process in which the needs and the circumstances of citizens in the developing world are put first in order to develop appropriate, adaptive, affordable and accessible products and services for emerging markets. In this approach frugal innovation is applied to improve the living standards of the poor. Similarly, open access artificial intelligence can be used to spur frugal innovation because open access is primarily free (Albert, 2019). Hence, it would be appropriate to use the software or algorithms to solve health issues or other critical problems and challenges in the society.

Frugal innovation can be used to improve products and services. As the overall process of frugal innovation reconfigures value chain, redesign products and eventually invents new business models in a scalable and sustainable manner (Vadekkepat, Garg, Loh and Tham, 2015). A good illustration of frugal in services is along education, energy, training, banking, and communication. From a product point of view, frugal innovation can be applied in housing, medical devices and automobiles. Likewise, open access artificial intelligence as a frugal innovation tool to solve the problems and challenges in developing countries. As suggested by Mirondo, (2019) Tanzanians researchers can advised to come up with affordable frugal innovations with high functionality with available resources. This concept is further supported by Mirondo (2019) who purports that the policy should combine local knowledge with new technologies like Artificial intelligence while using the frugal innovation approach to create local products and services.

A good example of artificial intelligence in frugal innovation would be applying artificial intelligence in mobile money to determine who to lend money. There should be an open access artificial intelligence algorithms that can sift mobile users and determine their credibility and credit score. Once the score has been ascertained, then a mobile money loan can be granted to the mobile user. As argued by Prof Knorning who said Africa can devise innovation that can bridge the financial gap through financial inclusion via mobile money like M-pesa, Tigo-pesa, and halopesa (As stated in Mirondo, 2019). Prof. Knorning further recommended mobile money transfers which have enabled people at the grassroots level with no means of owning bank accounts to be financial empowered (As stated in Mirondo, 2019).

Another possible area for artificial intelligence in frugal innovation is healthcare services in Tanzania. According to Ramadhani (2019) Artificial intelligence is set to revolutionize the healthcare systems in Tanzania and targets at assisting and providing solutions to some of the main problems confronting healthcare providers especially those living in rural areas. Based on the World health organization (WHO), the Tanzanian doctor to patient ration stands at 1 doctor to every 20000 patient (1:20000), but artificial intelligence might ease such a burden through a mobile application or telemedicine which is set to transform the healthcare system in Tanzania (Ramadhani, 2019).

One of the significance advancement of AI in Tanzania is the youth taking initiatives to solve local problems. According to Mtambalike (2019) youths with AI-related startups and projects in Tanzania are trying to catch up with the rest of the world by coming up with innovative AI-based solutions to address problems in the health sector, agriculture sector, service delivery, education. Mtambalike further purports that Tanzanian youths are not left behind and they are making the most of it. The increased availability of open source platforms and knowledge sharing platforms such as Google AI and IBM Digital Nation Africa has created an opportunity for technology enthusiasts African youths to catch up with the technology, African researchers to carry research in AI-related fields and policymakers to learn the technology (Mtambalike, 2019).

Empirical Studies about Artificial Intelligence and Frugal Innovation in Tanzania

Frugal innovation is a subject gaining traction in Africa. Most of the scholars have devoted adequate resources in the exploration of frugal innovation in solving African problems. A study conducted by Dijk (2019) entitled “a green revolution using frugal innovations: crop insurance for Tanzania farmers. This study examined the best way to assist traditional small maize farmers in Tanzania to increase their production. The study suggests crop insurance as a necessary step to mitigate farming risk associated with low or no crop yield. In this case, artificial intelligence can be applied as frugal innovation to determine the amount of premium for crop insurance. These are some among many studies which are exploring the use of frugal innovation to solve local problems and challenges for ordinary Tanzanians. In this case, Artificial intelligence can be a potential solution to drive frugal innovation in Tanzania.

A number of studies have explored the concept of frugal innovation in different sectors in developing countries like Tanzania. A study conducted by Hyvarinen, Keskinen and Varis, (2016) explores the potential of frugal innovation as means fro the private sector to engage in water-related development challenges in Tanzania. The findings realized from this case study indicated that frugal innovation has tremendous potential due to the focus on affordable, no-frills solutions. Moreover, the study recognized the pitfalls of frugal innovations in the water sector. However, frugal innovation might be sustainable in the long-run.

III. RESEARCH METHODOLOGY

The main objective of this study was to explore the application of open source artificial intelligence to facilitate frugal innovation in Tanzania. Specifically, this study identified the government initiatives to promote open source artificial intelligence for frugal innovation in Tanzania. Concurrently, the studies also determine the private sectors initiatives to facilitate open source artificial intelligence for frugal innovation in Tanzania. Ultimately, the study examined higher learning institutions initiatives in implementation of

open source artificial intelligence for frugal innovation in Tanzania.

The study was qualitative in nature where content analysis was applied as the research design for this study. Content analysis was the most appropriate approach because the research design focuses on documents and records about government policies, private sector initiatives and higher learning participants in promoting open source artificial intelligence for frugal innovation in Tanzania (Masanja, 2018; 2019). A cross-sectional research method was applied where the documents were reviewed at a specific time. A list of documents were sought from the government, private sectors and higher learning institutions to determine their initiatives to promote open source artificial intelligence to foster frugal innovation in Tanzania.

A predetermined criteria checklist was prepared based on the literature review and specific initiative guidelines were established. The checklist included policies proposed and implemented, funding available, Government or organizational strategic plan and other non-financial resource dedicated to promote open source artificial intelligence. The study will determine whether these criterions have been meet or implemented by the government, private sector and higher learning institutions.

IV. RESULTS

The results were presented based on the predetermined research objectives and questions identified in the study.

Government initiatives in the implementation of Artificial Intelligence for Frugal Innovation in Tanzania

The content analysis focused on 4 key criterions as government initiatives for the implementation of artificial intelligence in Tanzania. The first criterion was policy proposed and implemented for Artificial intelligence in Tanzania. The second criterion was government allocation of funding for artificial intelligence in Tanzania. The third criterion was identification of Artificial intelligence in the Tanzanian strategic plan. The forth and last criterion is the allocation of non-financial resources like Time and Manpower into the exploration of artificial intelligence in Tanzania.

Based on the content analysis on Policy Implementation for Open Source Artificial Intelligence for Frugal innovation, there are no specific policies which promote the implementation of artificial intelligence for innovative purposes in Tanzania. However, the former Director General of Tanzania Commission for Science and Technology (COSTECH), Dr. Hassan Mshinda said it is about time Tanzania takes note of the forth industrial revolution as other East African countries such as Kenya, Uganda and Rwanda have already commissioned task forces to guide them on the implementation of artificial intelligence (As stated in Lupatu, 2019).

According to the latest content analysis for government allocation of funds for artificial intelligence, there is little information about funding opportunities. At the same time, the government has allocated money into the ministry education, science and technology. However, there is a lack of specific funding for the implementation of artificial intelligence in Tanzania.

After an in-depth content analysis of the Tanzania Development Vision 2025 which provides a blue print of the long-term strategic plan of Tanzania, the study concluded that there were not funds allocated for artificial intelligence. Further analysis of the Government budget for 5 consecutive financial years (2015-2016, 2016-2017, 2017-2018, 2018-2019, 2019-2020) did not indicate any allocate funds for the implementation of artificial intelligence in Tanzania.

Further document review and analysis did not indicate other non-financial resources devoted into artificial intelligence as an approach to frugal innovation in Tanzania. There was no indication that the government had devoted time, labor or manpower to explore possibilities of artificial intelligence to promote frugal innovation in Tanzania. In summary, it is appropriate to conclude that the government has not taken any initiative to apply open source artificial intelligence to promote frugal innovation in Tanzania.

Private sector initiatives in the implementation of artificial intelligence for frugal innovation in Tanzania

Based on the same 4 criterions applied as the indicators for the implementation of artificial intelligence for frugal innovation in Tanzania, the content analysis revealed that the private sector has policies to implement artificial intelligence as an approach to frugal innovation in Tanzania. The content analysis revealed that companies like Sahara Ventures, Agrobot, E-shangazi, and Parrot AI are a few examples of the private sector start-up companies which are policies to promote Artificial intelligence in their business models.

Sahara ventures have the sole objective of building stable innovation, technology and entrepreneurship ecosystem in Africa though consultancy and investment. One of the key areas to fulfill their objective is artificial intelligence. According to the company website, business entity has a 15 managed projects and 10 organized events. Furthermore, This Company has managed to reach approximately 443 start-ups and 4000 entrepreneurs. In connection to this, Sahara ventures have an accelerator which supports early stage businesses, solving Africa's biggest challenges to grow. The Sahara accelerator has seven accelerator programs which are e-Kilimo accelerator, Lishe accelerator, AMUA accelerator 1 and 2, Hatua project, Mwanzo challenge and Botnar challenge which focuses on artificial intelligence and digital solutions to address challenges of the health sector and wellbeing among Tanzania youths. However based on the available data, the company is not reliant on open source artificial intelligence to foster frugal innovation.

Agrobot is another start-up with policies leading the way in artificial intelligence to assist farmers acquire appropriate and adequate information and advice regarding fertilizers, tools, medicine through a chatbox or a normal SMS message. This information is critical for increasing crop productivity and efficiencies in the farming process. According to Sahara ventures report published in 2019, Agrobot is among four agritech start-ups which have received a proof of concept fund from the kilimo accelerator. Agrobot was piloted with farmers located in Iringa, Morogoro and Dar-es-salaam. However, Agrobot were not using open source artificial intelligence for the frugal innovation.

E-shangazi is a knowledge sharing AI powered platform that provides education, information and advice about sexual reproductive health rights (SRHr) to the youth in Tanzania. This initiative has received seed funding from United Nations and Reproductive Health Agency (UNFPA) standito pilot the concept. E-shangazi is powered by three social media platform which are Facebook, Whatsapp and Slack. These platforms use curated contents developed based on laws, policies, guidelines and delivery standards set for health service provision, standard set by the government of the United Republic of Tanzania. The main objective of E-shangazi is to provide information about sexual reproductive health rights to young people. The language for communication is Swahili to make the information understandable for non-English speakers who are the majority in Tanzania. Most importantly, main premise of E-shangazi is to ensure confidentiality and privacy to access of SRHr

information. Furthermore, the start-up has partnered with Code for Africa to expand their healthcare content. However, the company had not initiative to apply open source artificial intelligence to facilitate frugal innovation.

Parrot AI is a new startup with the sole objective to transform the adoption of AI for business entities in Tanzania. Specifically, Parrot AI explores a business model of providing AI technology as a service to local business. This startup has a diverse group of professionals as data scientists, researchers, deep learning experts and ICT professionals from college of Informatics and Virtual Education at the University of Dodoma. In essence, this startup was founded by students and graduates from the University of Dodoma in Tanzania. According to Sahara Ventures report on AI in Tanzania, Parrot AI has been involved in several projects which include Applying Machine intelligence for agricultural disease, Detection, Identification and Mapping. In addition, Parrot AI has been engaged in Smart Urban which strengthens urban management capacity in developing world with Artificial Intelligence. Finally, the start also leverage machine learning in diagnosing urinary tract infections. This startup is spearheading the growth of AI through training and outreach programs to Tanzanians. They are supporting AI4Youth initiatives. However, there was not initiative to apply open source artificial intelligence to promote frugal innovation.

Table 1 provides a comprehensive and detailed analysis of the policies, funding, strategic plan and dedication of non-financial resources into the implementation of AI in the private sector.

Table 1: Criteria for AI in the Private Sector

Business Entity	Policies	Funding	Strategic Plan	Non-Financial Resources
Sahara Venture	Have policies for AI Accelerators and Startups	Dedicated Funding For AI	The plan focuses on AI in Tanzania	A dedication of Time and Experts in AI
Agrobox	Policies to use AI to acquire proper information about fertilizers, tools, medicine and diseases through chat box messaging or SMS	Received a proof of concept fund from E-kilimo accelerator	To expand from 3 cities (Iringa, Morogoro and Dar-es-salaam to other regions of Tanzania	A dedication of experts in AI technology and other supportive resources
E-Shangazi	Policies to educate, inform and advice youth on sexual reproductive health rights (SRHr)	Received seed funds from UNFPA to pilot the concept	The plan is partnering with reputed partners such as Code for Africa to diversify to other health contents	The startup has devoted non financial resource to meet it goals and objectives
Parrot AI	Policies of exploring business models of providing AI technology as a service to local businesses	Self funding initiatives and other sponsorship funds	Championing the growth of IA through training and outreach programs for university students	The devotes numerous non-financial resources

Source: Sahara Venture Report on AI in Tanzania.

AI projects in the Private Sector

Based on the Sahara Venture report of AI in Tanzania, the private sector leading the way with a number of AI projects. These AI projects tackle different problems and challenge facing ordinary Tanzanians.

A project developed by Ali Suleman and his team about the access to students loans to university students. This AI technology will assist the authentication of loans applications. Using AI, the application minimize human errors and corrupt official abusing the funds and reallocating the funds to the students in need. In addition, Ali Suleman with his team are applying learning on mobinet for facial authentication.

According to Sahara Ventures, this facial recognition project relies on mobinet models (Open Source AI) optimized to run on low powered devices with limited resources such as the basic phone (Frugal Device) to spur innovation. In essence, this project is a authentic demonstration of open source AI as an approach to facilitate frugal innovation in Tanzania.

Another project by Peresi Mgorozzi and his team are working on a project for early detector of maize disease. These project developers designed AI to automatically detect maize disease in the field using image capturing techniques. according to Sahara Venture report, the project use a data set created from images of the maize in the farm. The image in the data set is annotated by a domain expert. The data set involves 4 category label with 3 infected leaves and one healthy. They apply resnet50 model to extract the features from the earlier layer and train the classifier.

A similar project is the development of machine learning algorithm for classifying banana disease from the leaf image. According to Sahara Ventures (2019) this project is in the development phase by Davis David with his team. This AI technology will help farmers detect banana disease for small scale farmers. Specifically, the team is evaluating the application of transfer learning from a deep Convolutional Neural Network (CNN) model. In this case team applied various resnet models to evaluate the best results. In other words, the team conducted hype parameter search with the sole objective to determine the best hyper parameter that would provide the best results. These parameter include batch size, optimizer, momentum, learning rate, weight decay and model architecture (Sahara Ventures, 2019).

Artificial intelligence was also applied in healthcare predictions using data mining services. Salim Amour Diwani and his team are developing AI tools to assist new or experienced doctors in medical diagnosis and prognosis at the early phases of the diseases. The main purpose of the projects is to minimize healthcare costs, mortality and morbidity rate. The tools expected to increase efficiency in healthcare delivery. From a technical standpoint, the team is using raw data from Bombo Hospital CTC databases and as a result created CTC HIV databases with 9 attributes and 3527 instances (samples). The 9 attributes were weight, pregnancy status, TB screening ID, ARV status code, ARV code, CD4, WHO stage, Functional status code and ARV adherence code (Sahara Ventures, 2019). These were 9 attributes where used to determine the health status that is either good or poor.

Higher Learning Institutions initiatives in the implementation of artificial intelligence to promote frugal innovation among students in Tanzania

Referring the four criterions for the implementation, this section explores the AI initiatives taken by higher learning institutions. The University of Dodoma is implementing AI initiatives. Specifically, the college of informatics and virtual education (CIVE) in partnership with other stakeholders like Parrot AI, Pythontz, CIVE AI community. There have been

organized workshops, meeting and keynote session about artificial intelligence. Some of the sponsors are Sahara Ventures and Indaba. However, there were no policies, funding, strategic plan or even non-financial resources dedicated to Open source artificial intelligence.

St. Joseph University of Tanzania (SJUIT) has policies to promote AI development. According to Msikula (2019) A student from SJUIT pursuing a Bachelor in Electronic and Communication Engineering invented an AI robot. The student designed an intelligent robot to improve performance in diagnostic and treatment of heart related diseases. This process involved acquisition of information and rules for applying information and rules to attain approximate conclusion and self-correction. The innovation was presented at the 43rd Dar-es-salaam International Trade Fair (DITF).

From a technical point of view, the student proposed the measurement of seven prominent physiological parameter of a patient required by a physician at the clinic. The inventor further added the physiological parameter which include oxygen saturation in the blood (SpO₂), electrical activities of the heart (ECG), blood pressure, heart beats, weight, body temperature and height (Msikula, 2019). This parameter incorporation with ECG wave forms assist the AI in diagnosis of common heart diseases. These common diseases were congenital heart, rheumatic heart and vascular (aneurysm) diseases. To reach at such diagnostic results, AI will take the inputs from the sensors and information like age and blood from the management supporting software designed and analyze the inputs with other information from the database. This AI robot can diagnose accurately and prescriptions to the patient heart without a physician. However, there was no indication of the adoption of open source artificial intelligence to spur frugal innovation.

After a thorough analysis of existing literature, there were no statistics about the funding allocation of higher learning institutions on the implementation of AI in Tanzania. In addition, the strategic plan of several university and colleges did not identify AI as a strategic agenda for the institution. However, some institutions like University of Dodoma, University of Dar-es-salaam have devoted non-financial resources in AI. These resources include equipment, facilities, and experts in Information Communication Technology.

Funding provided for Open Source Artificial Intelligence for Frugal Innovation

Based on the content analysis for artificial intelligence, the document review realized that the government is investing less than 1% on AI or related areas. However, the private sector was investing a considerable amount of financial and non-financial resources in the development of AI technologies to solve the problems and challenges confronting normal Tanzanians. Figure 1 provides a summary of funding for AI by the government, private sector and higher learning institutions in Tanzania.

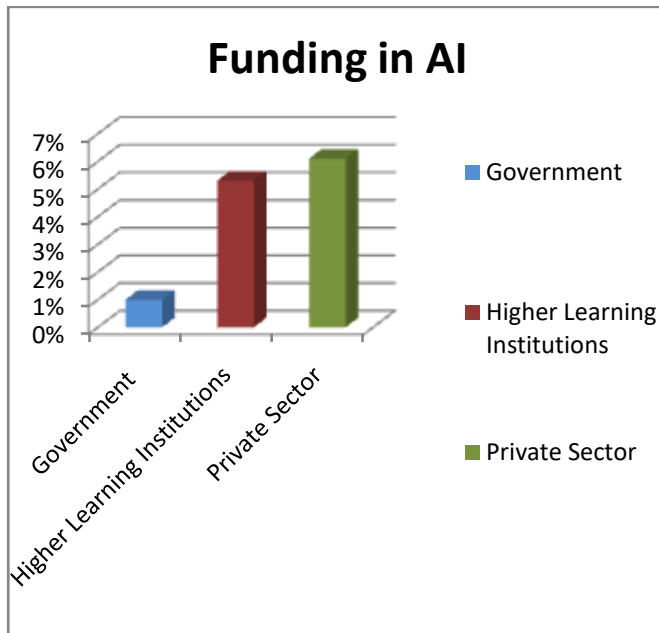


Fig 1: Bar Chart about Tanzania Funding in AI (Source: Content Analysis)

Percentage of Funding For AI in Tanzania

According the review of a number of documents, the majoring which was 49% of AI funding originated from the private sector. This is the reason for a number of AI solutions and project underway to solve problems and challenges facing Tanzania. At the same time, Higher learning institutions were also taking some AI initiatives. Higher learning institutions contributed approximately 43% of AI funding in Tanzania. Some examples were University of Dodoma and University of Dar-es-salaam. Other institutions are teaching AI as a course to spur innovative technologies in AI to solve problems and challenges in Tanzania. The government has the least funding of approximately 8% which is mostly allocated for science and technology. This includes advancement in technologies including AI. In this case, this is a considerable small amount compared to other stakeholders in AI initiatives in Tanzania. Figure 2 provides the percentage contribution of Funding for IA in Tanzania.

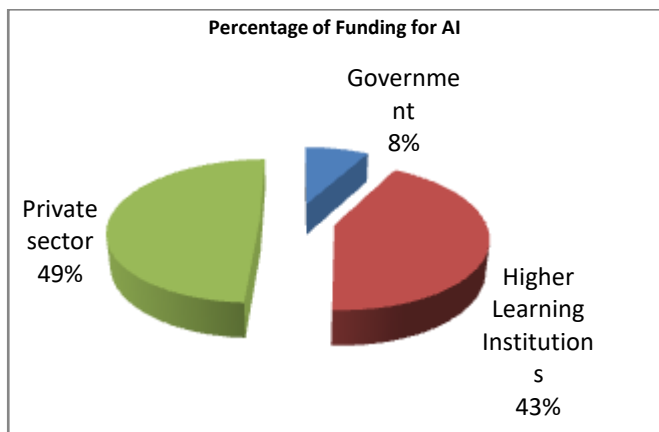


Fig 2: Funding for AI in Tanzania (Source: Content Analysis)

V. CONCLUSION AND RECOMMENDATIONS

This section provides the conclusion and possible recommendations based on the research findings regarding the application of open source artificial intelligence as an approach to frugal innovation in Tanzania.

Conclusion

Based on the finding about open source AI in Tanzania, AI is still a relatively new concept in Tanzania. This is due to the fact the government has not allocated financial and non-financial resources to the implementation of AI in Tanzania. Furthermore, the government has policies or legislation guiding the use and implementation of AI in Tanzania. But at the same time, AI has not been integrated in the strategic development plan for 2020. Specifically, Open source artificial intelligence has not been promoted at any level as an approach to promote frugal innovation in Tanzania.

On the other hand, the findings indicate that the private sector has made strides in the implementation of AI in Tanzania. The results revealed that the private sectors were using AI to solve problems and challenges facing Tanzania. These initiatives were in healthcare, agriculture, automotives and other sectors as well. There are a number of business entities which have embraced AI as a way forward to deal with the underlying problems and challenges in Tanzania. Furthermore, there are some companies which have relied on open access artificial intelligence to promote frugal innovation in different sectors. However, the number of business entities using open source artificial intelligence is limited compared to other African countries like Kenya, Nigeria, and South Africa.

The major findings reveal that Higher learning institutions were taking some initiatives to implement AI in solving challenges and problems in Tanzania. University of Dodoma though the college of informatics and virtual education (CIVE) in collaboration with other small start-ups in the private sectors. At the same time university of Dar-es-salaam are taking similar path to AI initiatives in Tanzania. Some other institutions are teaching AI as subject to spur frugal innovation. However, there were no record which shown the application of open source artificial intelligence to promote frugal innovation. In this case, these initiatives are relatively lower compared to other counties in Sub-Saharan African.

Theoretical and Conceptual Contribution

To gauge on the theoretical and conceptual contribution of this study, Artificial intelligence is still a relatively new concept in Tanzania. For this reason, this study provides an initial introduction of artificial intelligence as a means to frugal innovation in Tanzania. In other words, this study provides new insight for tapping into existing artificial intelligence which is open sources. This means instead of creating new artificial intelligence to address existing problems in developing countries, Tanzania can capitalize on existing open access artificial intelligence as Google AI. In addition to this, this article provides the starting point to think

about other technological innovations which are free and accessible so they can be applied to support frugal innovation in emerging countries like Tanzania.

Recommendations

Artificial intelligence especially open source artificial intelligence are still finding their footing in developing countries like Tanzania. Based on the collected and analyzed information on this subject, the following are initiatives to promote the implementation of open source artificial intelligence as an approach to frugal innovation in Tanzania.

The government should allocate financial and non financial resources toward artificial intelligence and specifically to open source artificial intelligence as a means to solve the problems and challenges facing Tanzania. Moreover, the government should introduce legislation and policies in support of open source artificial intelligence in solving problems and challenges in Tanzania. At the same time, open source artificial intelligence should be prioritized in the strategic development plan for Tanzania. Ultimately, the government should work in collaboration with the private sector and higher learning institutions to promote open source artificial intelligence in schools, business and in other sectors as well.

The private sectors should be aggressive in the promotion of open source artificial intelligence as the best approach toward frugal innovation in Tanzania. It takes a lot of financial and non-financial resources to develop new AI technologies to solve problems and challenges in Tanzania. Therefore, it is appropriate for the private sectors especially startups to rely on existing open source artificial intelligence to facilitate frugal innovation in Tanzania. First, it is cost-effective to use existing AI technologies; second, they are well tested AI models which have a track record and proof of concepts in solving challenges and problems. Third, existing open source AI reduces the time and manpower required to develop new AI technologies. For this reason, every startup should have the sole purpose to look for existing open source AI technologies to promote frugal innovation for different sectors in Tanzania.

Higher learning institutions should be leading the way in open source artificial intelligence as a strategy for frugal innovation in Tanzania. Institutions should have deliberate policies to encourage the exploration of open source artificial intelligence to develop cost effective technologies for challenges and problems in Tanzania. Due to the fact that higher learning institutions have knowledge, experience and considerable amount of financial and non-financial resources, they should dedicate their efforts though their students to develop appropriate innovations to solve problems and challenges in Tanzania.

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