Framework design for Machine Learning Integrated Mobile Based Livestock Disease Data Management, Diagnosis, and Treatment

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Abstract

The advancement of ICT opens the exciting potential to improve and maintain the quality of healthcare systems. However, the lack of detailed consideration of inclusiveness, usability, completeness, and localization with societal issues is still lagging in designing the next-generation intelligent systems. Upon the rigorous survey of the existing state-of-the-art studies, it was observed that the intelligent veterinary services with support the experts specifically in the far-flung rural areas over hand-held small mobile devices are still not fully explored. This approach in a country such as Ethiopia can significantly be a game-changing support system to assist in the medication of livestock. The prime goal of this paper is to investigate and analyze the problems associated with the existing systems and practices available in the field of livestock disease data collection, management, diagnosis, and detection and explore the possible intervention of machine learning with smartphone/mobile technologies in livestock disease data collection, management, diagnosis, treatment, and predictions Upon findings of the survey, interview, and technical observations, this paper proposes a machine learning-based mobile livestock disease data collection, data management, diagnosis, prediction, and treatment system framework for livestock using selected parameters to support and alleviate the existing challenges in veterinary service delivery systems.

Keywords: *Livestock, Disease Diagnosis, Veterinary service, Machine Learning, Hand held Devices, Framework.*

1. INTRODUCTION

Nowadays science and technologies are trying to alleviate poverty and support the sustainable development of a country and their societies in general. Specifically, it can also be used in solving the problems and challenges of veterinary-based economics. All across the world, the researcher's community has been consistently trying to explore the possible usage of science and technologies in several areas. The veterinary is one of the important fields in which the applications of science and technologies can be explored.

Currently, Ethiopia has more than 65 million cattle, 40 million sheep, 51 million goats, 11.0 million equines (horses, donkeys, and mules), 8 million camels, and 56.9 million poultry [1]. Despite having this large number of livestock, its contribution to the national economy is insignificant. Even though there are different factors, livestock infectious and parasitic disease takes the first place to affect the productivity of the sector negatively. If we fail to control these diseases, the country will be unable to achieve the objective of Growth Transformation Plan II (GTP II) namely poverty reduction, enhanced food security, to increase exports in terms of quality and quantity to improve foreign exchange earnings that attempted to meet in 2028 [1].

Promising access to quality and sustainable veterinary services is one of the most important parts to eradicate poverty in the world in general and in developing countries like Ethiopia in particular. As assured by different researchers, Livestock is an essential sector where efforts are being made to achieve and support the Sustainable Development Goals (SDGs) of the United Nations (UN) in economically developing countries [2]. As per the data produced by several agencies, Ethiopia is the first in Africa by owning huge livestock.

In this digital era, ICT has great potential to increase the rate of diffusion of a very wide range of technology, application, and platforms across developing countries. The key segment in which technology diffusion can be accelerated is healthcare. Additionally, the applications of ICTs have phenomenal potential to enhance information access, improve workflow, and help evidence-based practices to make informed and effective decisions directly by the specialists and their support staff at the point of care.

Today, information technology tools like smartphones and hand-held devices are considered powerful instruments for collecting, computing, distributing, and analyzing data for making evidence-based decisions. Besides, the advent of hand-held devices facilitates the diagnosis, prediction, and monitoring of risks associated with health [3] Yet, in the globe generally, in developing countries particularly, these technologies as a tool for diagnosis, treatment, and early detection of animal disease has not utilized their full potential in the livestock sector [4].

Despite several studies carried out on this problem not much devotion has been given to the community aspect rather than to technology in such a way that to answer 5w+h questions like what, what kind of tasks are going to be accomplished by the users, what components should be incorporated in the software product; who, to whom it will be designed and develop, who is the beneficiary, what are their characteristics this will answer to identify and include all the beneficiaries, Where, it refers the place where it will apply because beneficiaries vary from place to place; How, it refers the operation, how user operate to accomplish the

intended tasks, when, it refers the time the users use the software product, is it frequently or sometimes, considering such questions will help to reduce the problem associated with parameters desired to be improved such as User-friendliness, Localization, usability, Interoperability, sustainability, reliability, Inclusiveness and Expandability of the software products as well.

In developing countries like Ethiopia, despite efforts made to introduce mobile technologies for disease outbreak notification, livestock disease diagnosing, treatment remain disease data management is paper-based. But the intervention of these technologies in the sector not only enhances the veterinary service provision but largely benefits different stakeholders in the field as a result the economy of the country will develop. Thus, it is believed that applying smartphone technology in all aspects of livestock healthcare, predicting and data management has a significant contribution to socio-economic development and the life of the farmers and pastoralists.

This study has a great contribution to investigating the problem associated with all aspects of appropriate designing, development, implementation, and usage of smartphone technologies in the sector and helping animal health professionals and paraprofessionals to enhance their job performance. Moreover, the study will structure a base for policy makers to get data for making evidence-based decisions. To address the complexity and, to involve various stockholders and local users in the design, development, and implement smartphone livestock diseases diagnosis, surveillance, and control system; the existing systems are required to be reanalyzed for up-gradation with modernized technology-enabled systems and this has been revealed by several contemporary studies in Ethiopia [5].

To resolve the above-mentioned localized decision-making issues and challenges; a few research questions were initially formulated and they are - 1) What are the issues and challenges in the existing veterinary services delivery systems in general?, 2) What are the major gaps in-between the current state of the art (user interface model) and the modernized mobile enabled computing and communication system models for livestock disease diagnosis, treatment, predicting, data management and reporting system

To answer the research question as a whole; the prime objective of this paper was to set to investigate and analyze the problem associated with smartphone technologies in livestock healthcare, disease prediction, and disease data management. Further, it was also aimed to design and develop a localized machine-learning solution framework for Ethiopian livestock data management and treatment

2. Review of Related Works

Beckham, L.K. and Holmstrom T.R. (2017) surveyed and discussed various information technology tools, and their capabilities for supporting animal health workers in collecting, analyzing, and sharing livestock health data for appropriate animal health management, disease surveillance and response, and decision-making. The researcher made a detailed discussion on technologies namely: mobile health (mHealth) technologies, wireless sensors, and biosensors for remote data collection, crowdsourced and Internet-based data collection [4]. Nowadays the use of mobile is beyond reporting, it is used to compute, collaborate and communicate smartly, thus to have the maximum benefit from it, incorporating the major stakeholder is crucial. However, most of the research papers reviewed in this study showed that the researcher saw and

gave emphasis on the technology but to get acceptance by end users or numerous stakeholders to play a crucial role.

Reliable, high-quality, and timely data for decision-making is a prerequisite for effective animal healthcare systems. It is obvious that, if animal health data comes from different sources, integration could improve early detection and response to animal diseases and facilitate the early prevention of outbreaks [6]. Concerning this, it is clear that, using advanced technologies such as hand-held devices integrating with machine learning algorithms for data integration, analysis, computing, collaborating, and communicating play a great role in the livestock sector.

Researchers Colin Robertson et al. by recognizing the lack of research paper as they had got a research paper on human health in low-income and middle-income countries, researched a Mobile Phone-based Infectious Disease Surveillance System in Sri Lanka. The focus of the research was to collect animal health information in collaboration with forty field veterinarians recruited for this research purpose for nine months by using mobile phones. During the research time, nearly 4000 interactions were made with field veterinarian reports on the animal population received by the system. Finally, they conclude that the adoption of a Mobile Phone for an Infectious Disease Surveillance System beyond its reporting capability is found to be a means to empower field veterinarians with a valuable technological skill set for remote data collection. Improving veterinary public health awareness through training, communication, surveillance reporting, and the regular meeting is also another benefit of the project [7].

Researcher Mtema Z, et al. researched Mobile Phones as Surveillance tools implementing and evaluating a large-scale inter-sectoral in Tanzania to realize the research the system was developed in such a way that uses the Global System for Mobile communication (GSM) that allows an Internet connection to mobile phones through the General Packet Radio Service (GPRS) such system can work in the rural area even if 3G connections are not available [8] . For the sake of data-entry storage and data management, the system uses a data-entry application (openXdata) on Java-enabled mobile phones and employs an HTTP protocol to send data to a server running a MySQL database. The system developed in such a process was installed for 300 active users. The usability of the system was also evaluated by comparing it with a paper-based approach as a result they found that Monthly reports of bite patients submitted by phone (2011–2013) were over 400% higher than reports gathered from paper records (2005–2010). Additionally, the system is found to be more reliable and cost-effective in terms of massive data collection in a distributed way by maintaining its data quality, timeliness, and completeness. As a result, the surveillance serves as a tool to evaluate the effect of ongoing rabies control activities and progress in their management. Because of this, the health and veterinary sector considered the system a valuable tool for taking appropriate control measures for rabies disease [8].

Researchers Tariku J. et.al. Reported that new technologies such as smartphone applications have brought a new opportunity when compared to the conventional paper-based data collection and reporting in terms of obtaining consistent, complete demographic and epidemiological information, as well as distributing information in a timeliness manner for cattle diseases. Consequently, it is possible to improve disease reporting and surveillance

systems across low- and middle-income countries [9]. Smartphone format-based or electronic disease reporting systems play a fundamental role in avoiding data inconsistency, incompleteness, and time delay as compared to conventional (paper-based) reporting systems [5], [8]. The studies tried to address the importance of the technology, however, the sustainability of the technology in the business environment is determined by the end-user acceptance and customer satisfaction otherwise it lacks a sense of ownership as a result it opens a door for resisting the technology [10].

A study [5] was conducted in the domain but was not found flexible & scalable to accommodate other species and their diseases moreover the researcher focused on the technology part without considering the major stakeholders in the Ethiopian context. Research [11]contributes simple expert decision support. It uses the If-then rule which is monotonous. It does not show the flexibility to accommodate other diseases and species. It does not show the ranking of the disease to have a differential diagnosis which is important for appropriate treatment it lacks inclusiveness.

A semi-research project [12] has a significant contribution to the proposed research but it lacks showing methodology and participatory design which limits the effective use and sustainability of the technology in the business environment. Research [5]is relevant to meet the objective but lacks respective user participation in the design process and in terms of local context this may affect the acceptance and the use of the software. The study [13]is relevant to the proposed research study in this paper however the researcher focused only on the technology part and missed to incorporate major issues of users like veterinarians, and extension workers. Besides the study lacks to indicate the use of mobile for diagnosing, and treating animal diseases.

To sum-up, up rigorous literature reviews on important papers tried to address on adopting of machine learning and mobile technology either for a particular disease in particular species for instance [5], [9], [11], [12] for only cattle disease [8] Adopting of the mobile phone as a surveillance tool for rabies diseases. However, decision maker for instance: veterinarian, animal health assistant needs support to diagnose and treat different species of animals on the other hand researchers and policy makers also need information not only on particular species and diseases but also the possible diseases which affect the reproduction and productivity of livestock animals such as cattle, sheep, goat, camel, horse, donkey and mule besides the studies lacks incorporating major stakeholders in the design and development process which are the main components of the technologies Therefore there is a need to design and develop a framework that is flexible, expandable, scalable, customizable and can be inclusive

In animal healthcare, disease prediction and disease-related data management systems involve several actors to attain their objectives, identifying and incorporating appropriate participants and stakeholders is crucial for designing a framework and developing and implementing the software [14] product. Obtained from a preliminary survey, the salient actors in livestock healthcare, disease predicting, and disease data management systems are depicted in figure 1

Figure 1 salient actors of the veterinary medicine sector

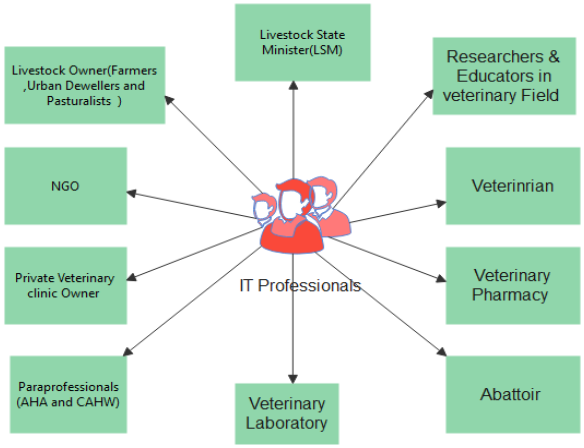


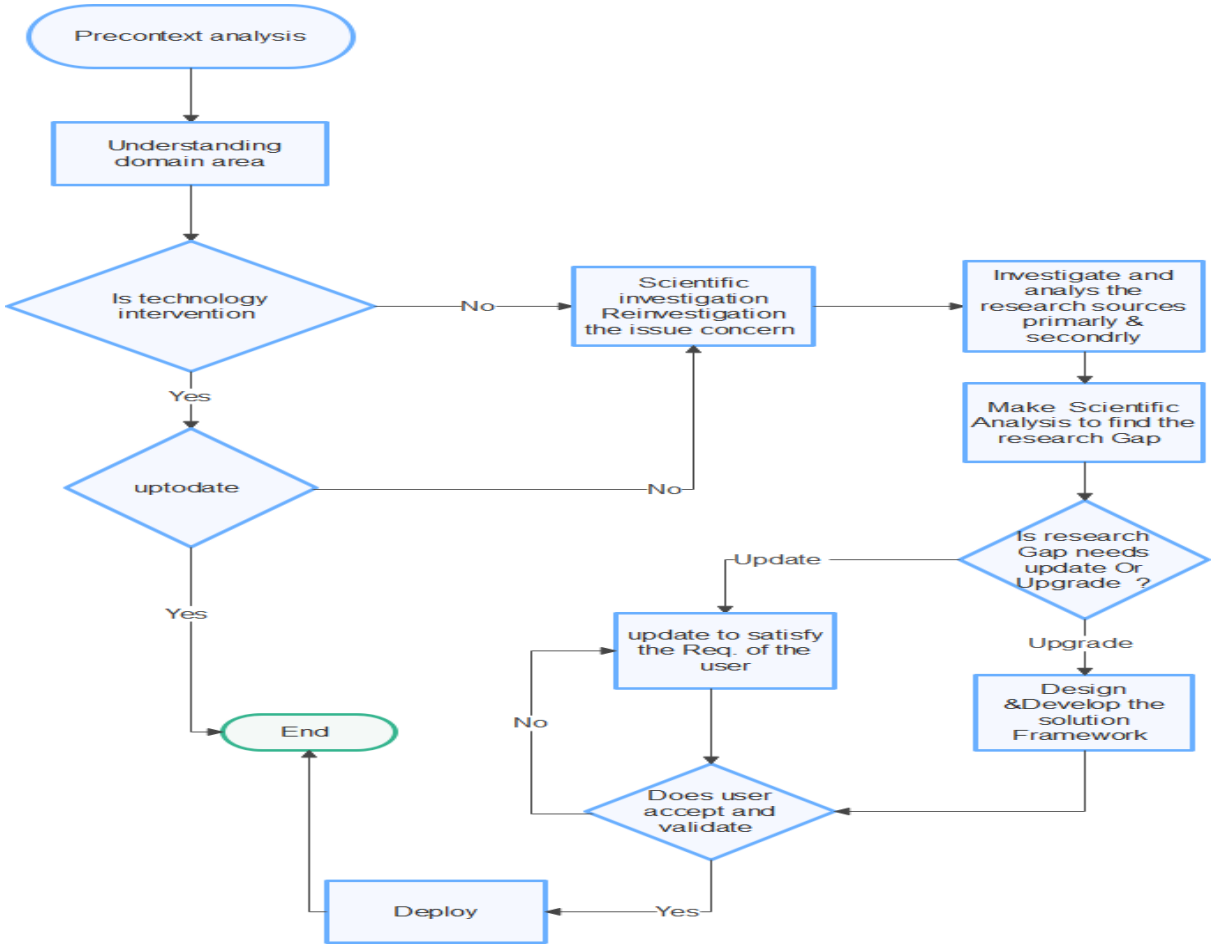
Table 1 Salient actors in the research study and their role description

S. No	Name of salient actors	Descriptions
	Livestock State Minister(LSM)	A government organization under the Ministry of Agriculture of the Federal Republic of Ethiopia, accountable for facilitating and designing policy for materializing the benefits of new technology and best practices to improve animal health services
	Researcher & Educator in the field of veterinary Medicine	An individual or group of people who graduated with a B.Sc. or above Degree from a known university engaged in teaching and research activities in Veterinary science [1]
	Veterinarian	They are professionals accountable for the health of Domestic and wild animals with the prevention of transmission of animal diseases [15]
	Animal Health Assistant (AHA)	Those who have formal qualifications such as Diploma or degree and they engaged mainly in animal health either assisting a veterinarian their role included providing primary veterinary care [16]
	Veterinary Pharmacy	Is a field of pharmacy practice, in which it compounds with drugs and therapies for animals
	Paraprofessionals Community Animal Health Worker (CAHW)	A person who for the Terrestrial Code, is authorized by a veterinary statutory body to carry out certain designated tasks [16]

	Private Veterinary clinic Owner	A veterinary clinic owned by private
	Veterinary Laboratory	It is an institution where different operations and procedures about animals, for example collecting specimens from their bodies, are performed for confirmation of the suspected diseases [1]
	Livestock Owner(Farmers, Urban Dwellers, and Pastoralists)	Individuals or groups of people who keep from small to a large number of livestock animals for sake of generating income
	IT professional	Communicate with all stakeholders to identify user requirements and validate the software product whether satisfies their needs or not
	NGO	"A nongovernmental organization (NGO) is an organization independent of the government whose primary mission is not commercial and that focuses on social, cultural, environmental, educational, and other issues."
	Abattoir	The place where animals are slaughtered to provide meat [17]

3. Investigating the Approach to the problem

Figure 2 investigating the problem and the research process



To alleviate the current livestock disease diagnosing, livestock disease data management and disease predicting system-related issues and challenges, there is a strong need for a localized solution Framework. This can meet the standard to be competitive globally in livestock healthcare and disease prediction systems. As a result, it can be a significant contribution to ensuring socio-economic development and the life of veterinary services delivery professionals and pastoralists. The proposed framework can improve the veterinary services delivery systems and it can be explained in terms of the following equation.

MLIMVS (Machine Learning Integrated Mobile based Veterinary Service)= $\frac{\int(Design, M.L.A, PL, NW, resources}{Stakeholder\ Objectives}) + f$ (Hand-held device Technology)

M.LA (Machine Learning Algorithm), PL (Programming Language), NW (Network),

In the above equation, the Machine Learning based Veterinary Services Delivery Systems are determined by the integration of different components for instance, how the software is designed and developed because the quality of a finished product is the result of the complete translation of design, hence if there is the problem in the design phase failure of a software project will occur. To make decisions regardless of time and distance, the availability of a network in terms of quality and coverage is a must. Recently smartphones have been recognized as the main backbone for businesses to increase the efficiency and effectiveness of veterinary service delivery systems. As revealed by scholars, the role of the smartphone in healthcare is not only for communication but for computing and collaboration as well as for minimizing the possible occurrence of medical error [18]. As presented in figure 4, the proposed ML integrated solution framework on mobile devices for veterinary services can be a transformation instrumental for Ethiopia. The proposed platform framework needs to be flexible, scalable, expandable, inclusive, user-friendly, localizable, and easily adaptable.

The proposed framework has several layered components which are described as follows-

Performance Layer: This layer is responsible to identify the goals met by each layer concerning the Architectural framework and parameters used to measure the selected standards. In the proposed architectural framework, there are different components engaged for the implementation, of the stakeholders' contribution toward achieving the intended goal. The performance layer indicates the relationship of each element in the group and how to measure the achievement as well.

Stakeholder layer: It is the layer that is responsible to identify the possible actors and their activities and its goal in each phase for the successful implementation of the system. As defined by the study [19], the stakeholder is a group, individual, or organization that may be affected by its activities or outcome throughout the process during the development phases or after the deployment of the project. As they have different opinions about the system, therefore, considering them to be involved in each phase of the development process, especially in analysis and design, will help to obtain a successful and acceptable software product or system. Therefore, identifying and incorporating appropriate stakeholders is crucial for the implementation of the proposed Improved Veterinary framework.

Domain Knowledge area Layer: It is a layer that guides to identify of the possible experts in which the investigation is done or extraction of data is done such as selecting species, disease priority and disease clinical symptom and

furtherly their weight in terms of numerical value were not possible to obtain without the involvement of the domain expert thus, this layer gives direction that what kind of data format, which domain expert needs to extract, and how to integrate are identified in this layer.

Machine learning layer: This layer is responsible for guiding how to select machine learning algorithms, as it is directly related to data because the performance of the machine learning algorithm is determined by the nature and characteristics of data and performance of the learning algorithms. Because of this, choosing an appropriate learning algorithm that fits the specific application is considered a challenge and well-studied [20]. In the proposed veterinary service framework, the layer has three components namely: Machine Learning Algorithm, Probability, and Disease Ranking i.e. based on the learning algorithm we can get the probability of the diseases. This in turn generates disease ranking to display differential diagnoses of the particular disease following this treatment can be done.

Taking this into consideration in the first phase, it can be decided to use Naïve Bayes' Rule (conditional probabilities). Because Naïve Bayes' Rule assumes conditional independence among attributes thus, it is good to discover facts in the exact situation, besides, it is a well-known classifier to solve the diagnostic problem in the medical area and the same has been studied in [16]. Different diseases may have several similar clinical symptoms however, there are one or more unique symptoms that help can animal health professionals to differentiate one particular disease from the others. Taking this into account, while implementing the framework, this research used Naïve Bayes 'rule to calculate the probabilities of each symptom for predicting certain diseases as follows-

$$P(X|Y) = \frac{P(Y|X)*P(X)}{P(Y)}$$

Where:

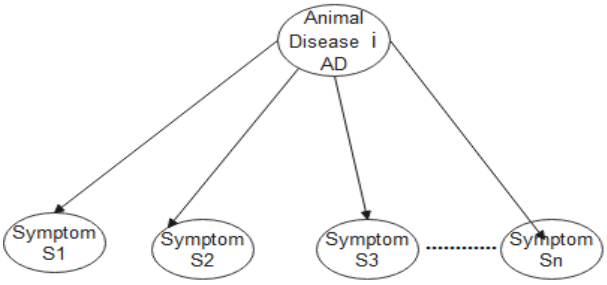
P(X) represents the prior probability. It is knowledge or uncertainty of a data object before observing it

P (X|Y) represents a posterior probability. It is knowledge obtained after observing the data object

P (Y|X) represents a likelihood probability. It is the probability belongs under a specific category or class, P(Y) represents the total observed evidence (Normalization). It is a marginal probability of the data

In the case of this research, as presented in figure 3, animal Disease is designated by (AD) whereas Symptom is designated by (S) by considering that Naïve Bayes assumption conditionally independence of variables (Symptoms) given the diseases.

Figure 3 Disease dependency on symptoms



P (AD, $Symptom1 \ldots Symptom_n$) = P (AD) $\prod_i^n P(Symptom1|AD)$ ……..Eqn 1

To find the probability of a particular disease without biases; it is important to normalize or marginalize, based on Bayes theorem. It will help us to get equal prior probability

$$P(AD|S) = \frac{P(S|AD)*P(AD)}{P(S)} \ldots\ldots\ldots \text{Eqn 2}$$

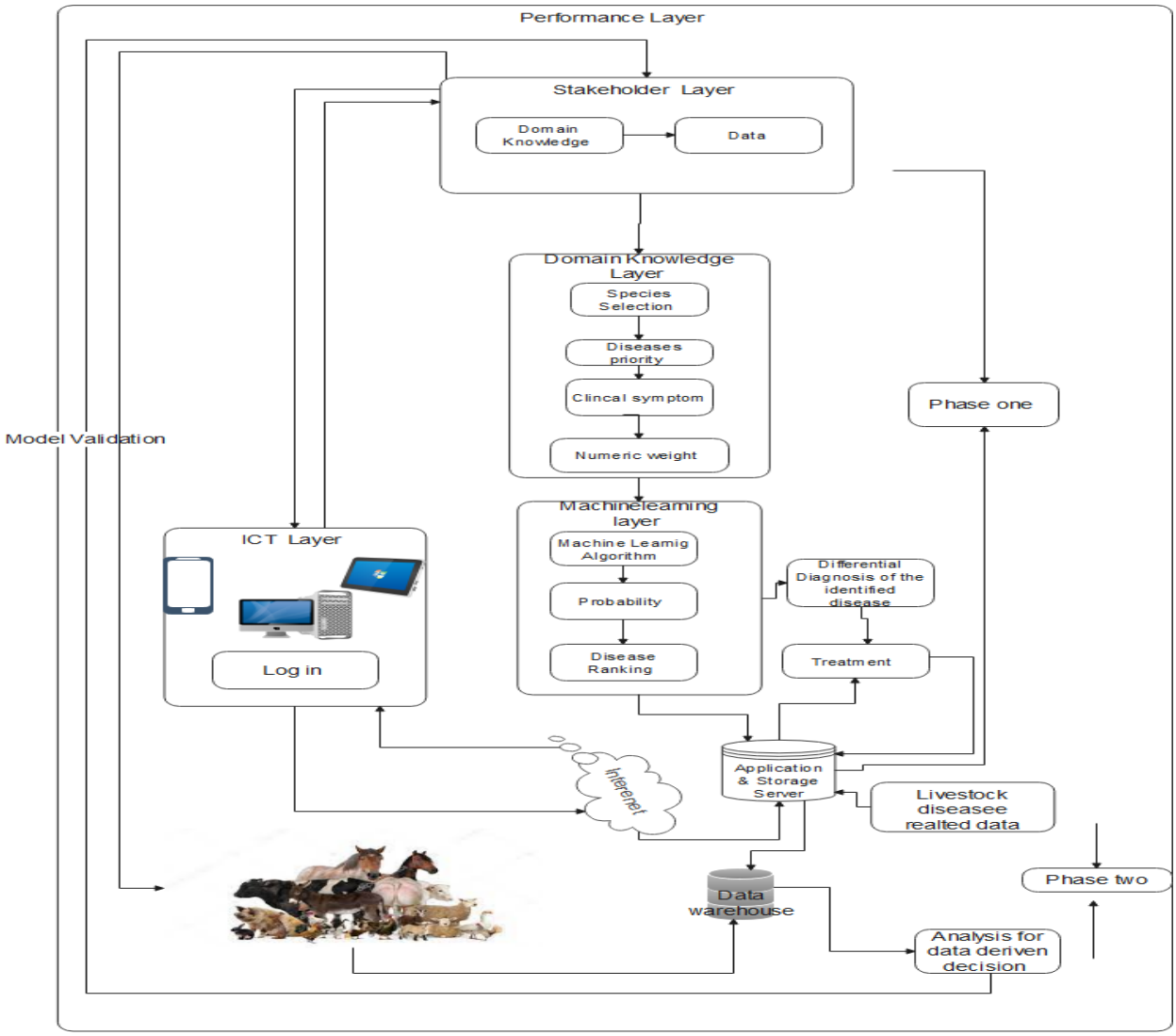
Since the probabilities of the clinical symptoms are obtained from domain expert $P(S|AD), so$ should be considered as the likelihood probability (the probability belongs to a particular disease, thus we have to expand the denominator as follows

$$P(AD|S) = \frac{P(S|AD)*P(AD)}{\sum_{i}^{n} P(S|AD)P(AD)} \quad \text{.....Eqn3}$$

There are three options to select the clinical symptoms: present, absent, and unknown that means if the animal shows the symptom listed on the screen it will take the probabilities taken from the domain expert (the likelihood). If the patient animal does not show symptom, it takes 1 for the probability value of the presented clinical symptom otherwise it will take 1 for unknown symptom since everything multiplied by 1 the value will remain the same (rule for identity number for multiplication)

By doing so, the probabilities of diseases will be generated according to the selected clinical symptoms on the displayed screen on a smartphone as a result disease ranking will be obtained to have a differential diagnosis. Upon the diagnosis result, the system will provide a treatment option.

Figure 4 machine learning Integrated Mobile-based Veterinary Service Framework



4. Conclusion and Recommendation

In the study, the existing state of art veterinary medicine delivery systems are assessed and the existing issues and challenges are investigated and thoroughly analyzed to design and develop an alternative Machine Learning Integrated Mobile-based Veterinary Service Delivery and Disease Predicting System Framework based on the context of beneficiary requirement .

Various issues and challenges in the current veterinary service delivery systems are investigated and analyzed based on the chosen parameters. Additionally, based on the study results and recommendations, the best alternative framework platform i.e., Machine Learning Integrated Mobile-based Veterinary Service Delivery System Framework is designed and validated on different parameters such as Localization, Inclusiveness, Accessibility, Completeness and user friendly etc which should be crucial for the sustainability of the software product in the business .

In addition, the research critically investigated the benefits and the limitations of the MLIMVS framework studied and analyzed wisely with different angles and parameters. At the time of data collection and analysis, based on the stakeholder and participant responses to the research questions and related issues and challenges; the researcher categorized the questions into three classes. The study site's veterinary service infrastructure belongs to B-type veterinary clinics so considering their demographic information has no great significance to change the finding result. Among the second category of research questions 40% and 38% of the respondents responded were writing the history of the patient animals in the case book and handling many cases at a time are frequent challenges respectively. On the research outcomes, 82.56% of respondents strongly agreed that the intervention of smartphones can improve the current veterinary service delivery system. 73.53% of the respondent have no awareness using of smartphones in veterinary service provisions similarly 71% of the respondents strongly agreed to use a smartphone in a veterinary clinic. Equally 90% of the respondent believed that using smartphones in the veterinary clinic can benefit the professionals in different activities to improve the service delivery system. As per the data collected from salient stakeholders and users, the traditional/conventional veterinary services delivery system still has not shown any improvements to change the life of farmers, veterinary practitioners, and pastoralists.

The design, evaluation, and validation of the proposed MLIMVS Solution Framework can be considered a revolutionary transformation instrument for the veterinary sector of Ethiopia. If the solution proposed by the framework is well-designed and deployed in the country, it can change and establish a new paradigm of veterinary services in Ethiopia through appropriate livestock disease data management.

4.1 Recommendation

We are conscious of the potential for additional design challenges and the fact that these parameters cannot be universally applied to settings in various countries.

In a series of workshops, we will create an agile and participatory framework for our future work involving design prototyping with key stakeholders. The entire proof of concept will then be implemented in a real-world situation in order to record (or evaluate) the design process and usage pattern.

Author Contributions: Conceptualization, investigation, data curation and formal analysis and writing original draft preparation Mohammed K, Reviewing Editing and Supervision Professor Druga Prasad Sharma and Doctor Hussein Seid W and technical support Dr.Ravindra Babu.B. All authors have read and agreed to the published version of the manuscript.

Ethical clearance: To accomplish the research, the necessary data was collected with the permission of Ministry of Agriculture of Ethiopia through official letter, upon requested by the University Ref No:A/A/S/T./U/C/E /14/21 accordingly, the researcher visited different selected veterinary clinics in the country.

Conflict of interest: This research work is my part of PhD research work there is no conflicts of interest among authors

Funding: Currently, I am PhD scholars in software engineering at Addis Ababa Science & Technology University there is no fund allocated

Acknowledgement: We would appreciate and forward our gratitude to our collaborating organization specially Faculty of veterinary medicine of Addis Ababa University and East Showa Zone veterinary office administrators allowing us to conduct field observation in their vet clinic, and for facilitating to conduct different workshop. Thanks to Ethiopian Emerging biotechnology for sponsoring purchased Smartphones for field testing and organizing workshop.

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