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Leveraging Expert Knowledge for Mobile Livestock Care: Combining AHP and Naïve Bayes for Diagnosis, Treatment, and Management

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Abstract:

This study successfully designed and developed a smartphone application for livestock disease diagnosis, treatment, and reporting. The agile development framework Extreme Programming (XP) ensured efficient iteration and adaptation based on user feedback. Additionally, the integration of the Analytical Hierarchy Process (AHP) with veterinary expert input facilitated the prioritization of disease possibilities within the app. Furthermore, the application of Naive Bayes probability allowed the system to rank diseases based on them likelihood, enhancing the accuracy of diagnoses. Workshops, field observations, group discussions, and interviews with senior veterinary experts were used as data collecting and final product assessment tools to ensure it met the original criteria. Purposive sampling was used to distribute the application to 90 smartphone users who work in veterinary clinics, including 49 senior veterinary medicine students. The proposed system offers benefits such as improved healthcare access, early disease detection, enhanced disease management, and strengthened livestock health surveillance. This multifaceted approach holds significant promise for improving livestock health management, particularly in resource-limited settings.

Keywords: Extreme Programming, User Centred Design, Smartphone, Livestock Diseases Management and Analytical Hierarchical Process Model.

1 INTRODUCTION

Livestock diseases pose a significant threat to the livelihoods and food security of smallholder farmers in Ethiopia, a developing country with limited access to veterinary services. Early diagnosis of diseases is often hampered by lack of qualified veterinarians and diagnostic tools in rural areas. Traditional disease reporting systems are paper-based, slow, and lack detailed information, hindering effective disease control and prevention strategies [1],[2]. Delayed diagnosis and treatment lead to increased mortality rates, decreased productivity, and economic losses for farmers. Timely diagnosis allows Animal Health Professionals (AHP) to implement treatment sooner, increasing animal survival rates and productivity [2]. Access to treatment recommendations and best practices empower AHP to make informed decisions regarding animal care and management. Reduced livestock mortality and increased productivity lead to higher income and improved livelihoods for farmers. Recently, the advancement

of information technology tools such as smartphones add value to the business, the business to be competitive and sustainable in its environment the adoption of this technology is vital. In line with this, considering the stakeholder while designing and developing the software is also a core element for the acceptance and use of the technology. Hence, the consideration of user and customer involvement in different phases of software design and development processes is important. All activities involved in software development such as planning, analysis, design, coding, testing and maintenance are to be aligned to customer needs and satisfaction [3]. While most research focuses on agile methodologies within software companies, its application for in-house software development deserves exploration. When both customers and users are key stakeholders, actively involving them throughout the development process can maximize the benefits of information and communication technology (ICT), particularly on smartphones. Traditional methodologies like Waterfall, Spiral, V-model, and Incremental struggle to keep pace with the dynamic business environment and ever-changing customer needs. Their reliance on detailed, upfront planning proves difficult when requirements are constantly evolving [4]. The ever-changing nature of business requirements necessitates a software development methodology that can adapt and deliver value continuously. This shift towards lightweight methodologies like Agile reflects this need, allowing software designers and developers to prioritize customer satisfaction in a dynamic environment.

While existing research explores Agile methodologies in software development companies with a focus on customer satisfaction, there's a gap in understanding how Agile works in in- house software development, particularly when prioritizing user needs for long-term product adoption and sustainability [5]. This study explores the use of user-cantered design (UCD) combined with Extreme Programming (XP), a lightweight Agile methodology, to develop smartphone applications for animal health professionals. The goal is to create efficient and effective tools that empower them to deliver veterinary services. Recognizing the importance of user buy-in, we will actively involve both users (veterinarians) and customers (the veterinary practices) throughout the design and development process. This collaborative approach is crucial for managing the evolving nature of user requirements and ensuring the final product's successful adoption.

2 BACKGROUND

As a PhD candidate in Software Engineering at Addis Ababa Science and Technology University, my research focuses on developing a framework for a Machine Learning-supported Intelligent Veterinary Service System using mobile devices. This system aims to empower animal health professionals in Ethiopia, including veterinarians, Animal Health Assistants (AHAs), and Community Animal Health Workers (CAHWs). In Ethiopia, especially remote area veterinary service delivery relies heavily on paraprofessionals like AHAs and CAHWs who serve rural communities. The mobile application will support both professionals (junior veterinarians) and paraprofessionals in diagnosing, treating, preventing livestock diseases and data management. To ensure the research is scientifically sound, I have assembled a team of experts. The team comprises four software engineering and computer science specialists with postgraduate degrees (MSc. to PhD) and four veterinary medicine domain experts who are all Associate Professors. Furthermore, we are utilizing Extreme Programming (XP) to facilitate the development of a functional application within a short timeframe, ultimately enhancing the capabilities of animal health professionals in Ethiopia

3 AGILE SOFTWARE DEVELOPMENT METHODOLOGY (ASDM)

Extreme Programming (XP), the chosen methodology for this project, falls under the umbrella of agile software development. Agile methodologies prioritize an iterative and cyclical approach, emphasizing continuous planning, development, and feedback loops throughout the project lifecycle [6]. As noted by Teka et al. (2018), agile methodologies are lightweight approaches to software development. This translates to two key benefits: the ability to adapt to evolving requirements even during later stages of development, and the rapid creation of prototypes to validate those requirements.[7]. Agile software development methodologies, known for their speed and adaptability, are ideally suited for the dynamic world of mobile applications. This is because Agile emphasizes iterative development with short cycles, allowing for continuous adaptation to changing requirements [7] The rapid growth of mobile technology has fuelled a surge in demand for mobile apps, leading to a corresponding increase in mobile app development projects [8]. However, these projects often face highly volatile requirements, presenting challenges for designers and developers [9]. Agile's flexible nature, allowing for adjustments even in later stages, makes it a powerful tool for navigating this dynamic environment. The ever-changing nature of mobile app development projects, with their volatile requirements, necessitates a flexible development approach. This has led software developers to increasingly embrace agile methodologies, particularly Extreme Programming (XP) [3][9] [10][11] XP aligns perfectly with the demands of mobile app development. As highlighted by [12], it prioritizes rapid development cycles, continuous customer involvement, and the delivery of functional code early and often. This iterative approach allows for gathering user and customer feedback throughout the process, ensuring the final product meets evolving needs. Furthermore, as noted in [13], XP is well-suited for small to medium-sized projects and in- house development, which are common scenarios for mobile app development. XP has five stages of the development practice that Iterate continuously

- ✓ Planning, this is the first stage in which the customer meets the development team and presents the requirements in the form of user stories to explain the required outcome. Following this the team prepares the estimation stories and creates a release plan broken down into iteration needed to cover the required functionality one by one.
- ✓ Designing it is the major part of the planning process, the design should be simple in such a way that to avoid unnecessary complexities and redundancies
- ✓ Coding this phase is the stage where the actual code is created by practicing specific rule and principles of XP listed in figure 1
- ✓ Testing is the core of XP, it is an activity that will be done regularly in both unit and acceptance tests to confirm whether the developed features work properly or not.
- ✓ Listening this is the stage where we regularly communicate and collect feedback in order to include for the next release to improve the software product.

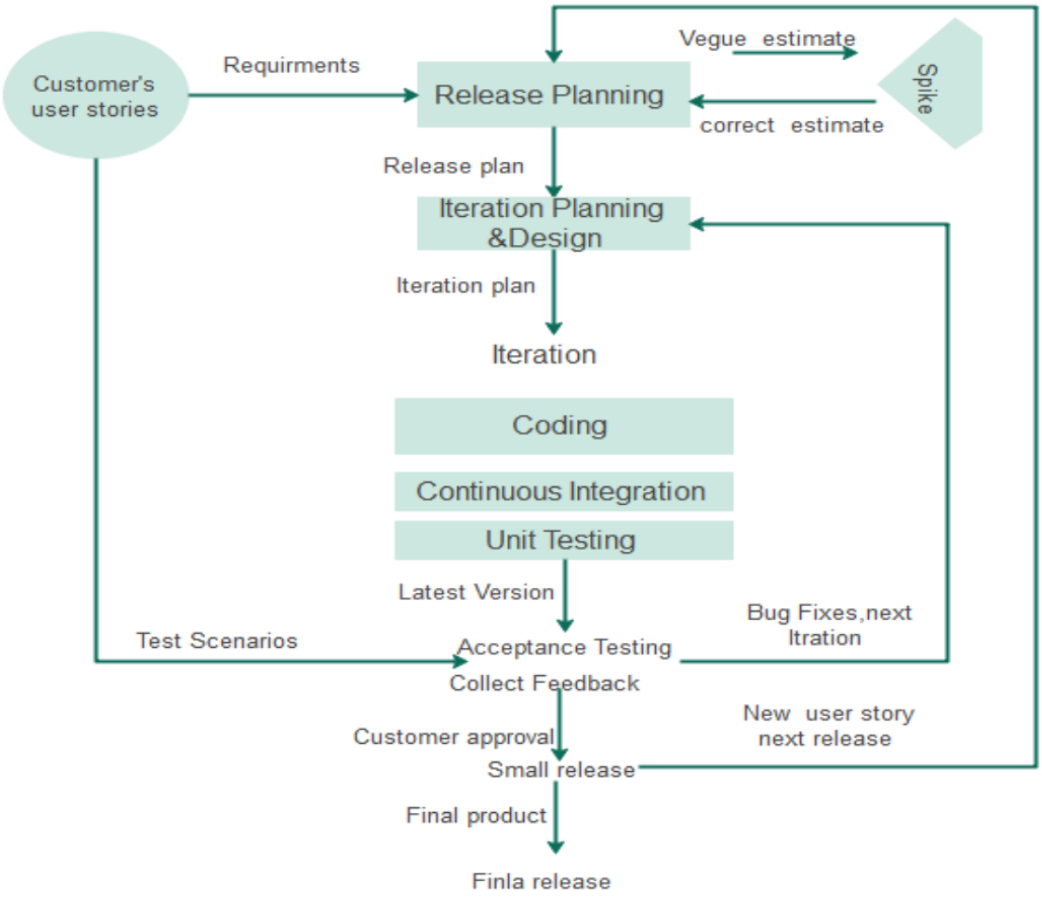

Figure 1: Extreme Programming Lifecycle [8]

In conclusion, agile methodologies have emerged as a dominant force in software development due to their key strengths: adaptability to changing requirements, flexibility, iterative delivery, and continuous customer interaction. These attributes make them far more suitable for mobile app development compared to traditional, rigid models. Research supports this notion, with scholars widely acknowledging agile's natural fit for the dynamic and user-centric world of mobile app development [3]

4 RESEARCH QUESTION AND METHODOLOGY

4.1 Research question

1. How can Extreme Programming (XP) combined with user-centered design principles be used to develop mobile applications that empower veterinary professionals and paraprofessionals?
2. Can the Analytical Hierarchical Process (AHP) combined with Naive Bayes probability be effective tools for gathering and incorporating expert opinions during the development of mobile applications for livestock disease management?

4.2 Methodology

As a methodology, we employed Extreme Programming (XP), an agile development framework, alongside user-centered design principles, to develop the Android mobile application. This case study explores the benefits of this approach for creating a tool that empowers veterinary professionals and

paraprofessionals, specifically focusing on improving the efficiency and effectiveness of livestock disease management services in rural Ethiopia.

4.2.1 Data collection methods

To gather comprehensive qualitative data, this workshop employed a combination of methods including interviews, focus group discussions, document assessment, and purposive sampling. Workshops, as highlighted by Ørngreen and Levinsen (2017) provide a valuable platform for researchers to explore relevant factors in a particular domain [13]. In our case, the workshop facilitated discussions and collaboration among diverse stakeholders (veterinarians, paraprofessionals) to gain insights into their experiences and needs related to livestock disease management using mobile technology. Following an initial analysis of existing information and discussions with a key study member, we conducted a workshop inspired by the practices of Katja Thoring et al. (2020) [14]. This workshop aimed to gather insights from stakeholders, particularly domain experts in veterinary medicine, using purposive sampling. Workshop Structure: First: Welcome and Introduction: A designated focal person welcomed participants and provided a clear overview of the workshop's objectives. Second: Identifying Livestock Diseases and Symptoms: Participants were invited to collaboratively list out common livestock diseases and their corresponding clinical signs on provided forms.

Third: Reaching Consensus: Through expert discussion, we identified possible diseases impacting livestock production and reproduction, along with the most frequently observed symptoms. Fourth: Likelihood Probability Assessment: Once a consensus was reached on diseases and symptoms, the workshop transitioned to focus on symptom probability. Experts, grouped by seating arrangement into five clusters (Clusters 1-5), leveraged their experience to estimate the likelihood of each symptom occurring for specific diseases. This information was collected in a comprehensive disease matrix table as follows

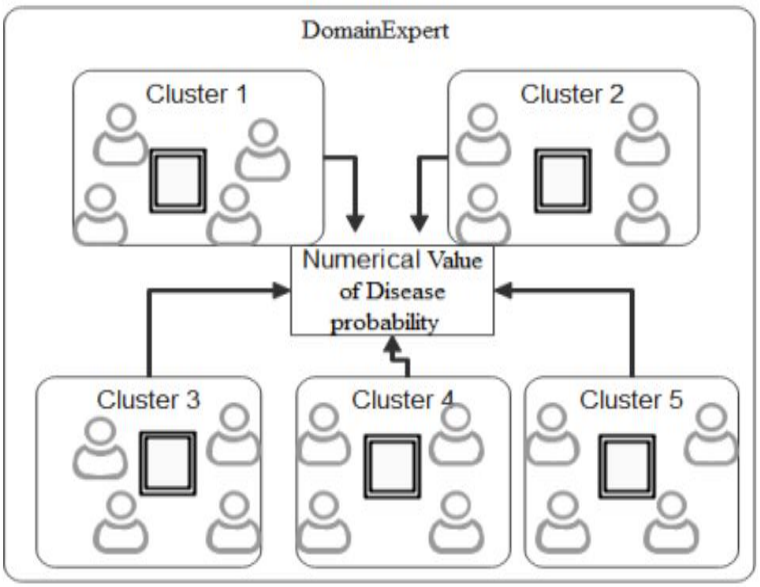

Figure 2: Process Of Data Collection From Veterinary Experts

To enhance our livestock disease diagnosis system, we employed a combined approach leveraging the strengths of both the Analytic Hierarchy Process (AHP) and Naive Bayes models. AHP, developed by Thomas Saaty (2014), is a structured method for making complex decisions with multiple criteria [15]. In our case, AHP will be used to systematically gather and analyze expert opinions to prioritize and weigh various factors crucial for disease diagnosis. AHP is a valuable tool for collecting and analyzing expert opinions in complex decision- making scenarios, making it a good fit for our livestock disease diagnosis system. This combined approach integrates AHP's strength in structuring expert knowledge with the probabilistic reasoning capabilities of Naive Bayes. The AHP can guide users through the decision-making process for diagnosis, while the Naive Bayes model provides probabilistic classification based on user input.

TABLE 1: Using AHP to collect expert opinion

Clinical symptom for particular disease(I)	Numerical Weight ↓	Probabilities of symptoms for particular disease(I)				
S1	Excellent=5(1.00) Very Good=4(0.6) Good=(3(0.3) Fair=2(0.1) Poor=1(0.00)	0-5%	5-25%	25-75%	75-95%	95-100%
S2						
….						
Sn						

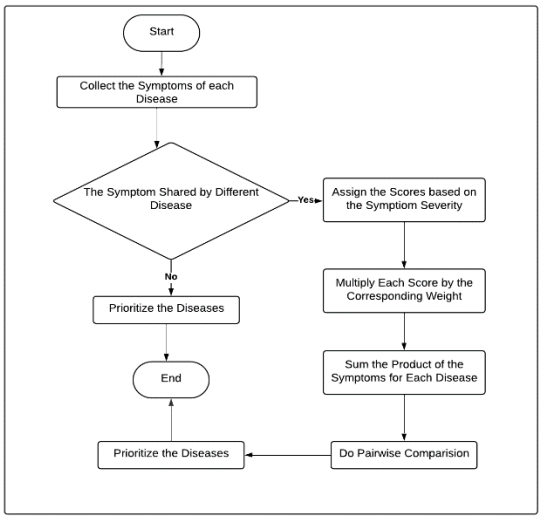

Figure 3: Process of AHP Model for Disease Diagnosis Approach to Prioritizing Diagnostic Tests and Symptoms Based on Expert Knowledge.

Through this method they were informed to write a numeric weight for likelihood probability of each symptom for a particular disease. By doing so we prepared a disease matrix using average weight of data collected from domain experts in order to make ready the data for software developers" to make it clearer and more concise. The whole process depicted in figure4

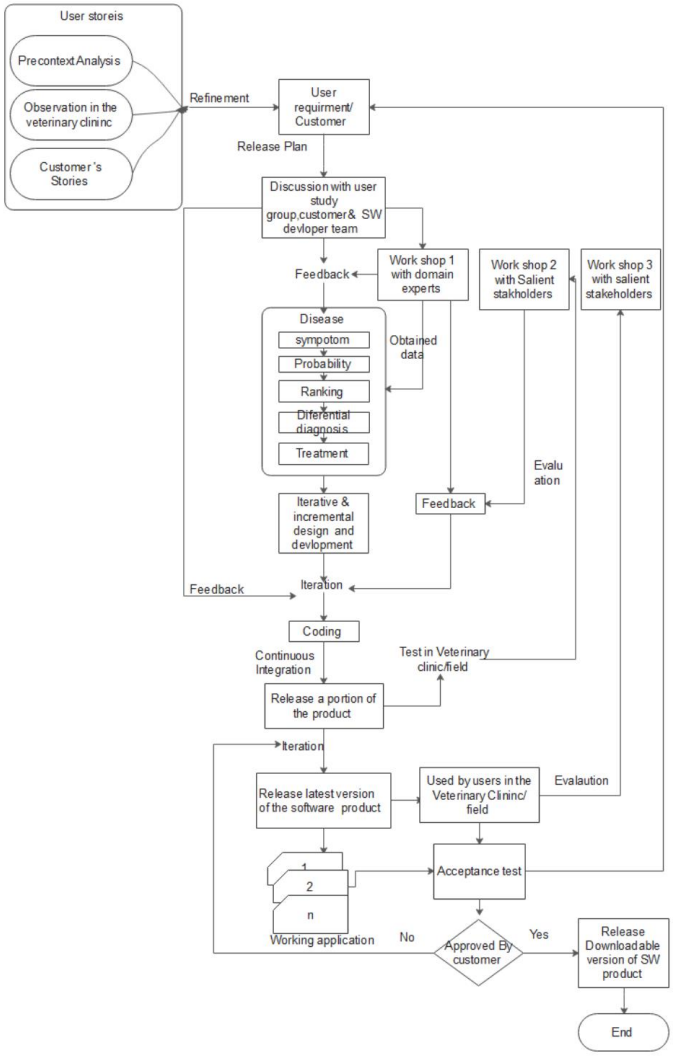

Figure 4: The Flow of Developing a Mobile App In User Centred Design With Extreme Programming

5 EVALUATION

Evaluation: Researchers assessed how well the product met customer and user needs by analyzing feedback gathered through workshops, field observations, group discussions, and interviews. Notably, the second and third workshops specifically focused on product evaluation with the participation of stakeholders, including software professionals. The qualitative analysis of the results was facilitated by the fact that the software was designed and developed in a central location where most users and customers work. This proximity fostered smooth communication and discussions throughout the iterative and incremental development Process Report turnaround time: This went from monthly to "on the spot" after software implementation, suggesting a significant improvement in efficiency. User

adoption rate. The increasing volume of data sent to the server from most regions across the country suggests widespread adoption of the software by trained professionals. However, areas lacking peace and security likely have lower usage.

Figure 5: Training On How to Use the Software

Figure 6: Sample Collection and Field Testing of App Accuracy for Disease Trypanosomiasis

6 CONCLUSION

This study successfully designed and developed a smartphone application for livestock disease diagnosis, treatment, and reporting. The agile development framework ensured efficient iteration and adaptation based on user feedback. Additionally, the integration of the Analytical Hierarchy Process (AHP) with veterinary expert input facilitated the prioritization of disease possibilities within the app. Furthermore, the application of Naive Bayes probability allowed the system to rank diseases based on their likelihood, enhancing the accuracy of diagnoses. This multifaceted approach holds significant promise for improving livestock health management, particularly in resource-limited settings.

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