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Canine visceral leishmaniasis surveillance and monitoring application (PampaCare LVC) – a One Health approach in Uruguaiana (RS)

Aplicativo de vigilância e monitoramento de leishmaniose visceral canina (PampaCare LVC) – uma abordagem Saúde Única em Uruguaiana (RS)

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ABSTRACT

Introduction: Uruguaiana, a transmission area for Visceral Leishmaniasis (VL), is one of the five municipalities in Rio Grande do Sul with cases of Human Visceral Leishmaniasis (HVL). **Objective:** To introduce the development stages of PampaCare LVC as an application on the PampaCare platform, developed for monitoring and analyzing information on various diseases. **Method:** The application was designed to provide the migration process from a legacy system based on manual filling of forms to an automated tool. The development included the steps of gathering requirements, specifying use cases, defining the architecture, implementation, documentation and support. Flutter and Firebase technologies allowed for fast and efficient development while maintaining data quality and authentication security. 22 requirements were defined, translated into application functionalities. **Results:** The notification, geolocation of cases, data recording, report generation and epidemiological analysis stood out as functionalities. This information will help in the construction of alerts regarding the epidemiological situation of the neighborhoods, contributing to the environmental surveillance of territorial base in an assertive way. The Minimum Viable Product version was made available to the Environmental Health Surveillance Office in April 2023 and the final version will be released in August 2023. **Conclusions:** The application complied with 76% of the subcategories evaluated by the self-assessment technique, presenting satisfactory performance in terms of user experience and usability. After the updates, it is intended to reach 92% coverage of the subcategories that are part of the evaluation tool. Access to information from clinics and hospitals will enable greater robustness to the disease indicators, allowing the elaboration of public policies consistent with the reality in Uruguaiana.

KEYWORDS: Leishmaniasis; One Health; Health Information Systems

RESUMO

Introdução: Uruguaiana, área de transmissão da leishmaniose visceral (LV), é um dos cinco municípios gaúchos com casos de leishmaniose visceral humana (LVH). **Objetivo:** Apresentar as etapas de desenvolvimento do PampaCare LVC como um aplicativo da plataforma PampaCare, desenvolvido para o monitoramento e a análise de informações de diversas doenças. **Método:** O aplicativo foi elaborado para proporcionar o processo de migração de um sistema legado baseado no preenchimento manual de fichas para uma ferramenta automatizada. O desenvolvimento contemplou as etapas de: coleta de requisitos, especificação de casos de uso, definição da arquitetura, implementação, documentação e suporte. As tecnologias *Flutter* e *Firebase* permitiram o desenvolvimento rápido e eficiente, mantendo a qualidade dos dados e segurança na autenticação. Foram definidos 22 requisitos, traduzidos em funcionalidades do aplicativo. **Resultados:** Destacaram-se como funcionalidades: a notificação, a geolocalização dos casos, o registro

de dados, a geração de relatórios e a análise epidemiológica. Estas informações auxiliarão na construção de alertas referentes à situação epidemiológica dos bairros, contribuindo para a vigilância ambiental de base territorial de forma assertiva. A versão MVP (*minimum viable product*) foi disponibilizada para a Vigilância Ambiental em Saúde em abril de 2023 e sua versão final será liberada em agosto de 2023. **Conclusões:** O aplicativo cumpriu com 76% das subcategorias avaliadas pela técnica de autoavaliação, apresentando um desempenho satisfatório quanto à experiência de usuário e usabilidade. Após as atualizações, deseja-se alcançar 92% de cobertura das subcategorias integrantes da ferramenta de avaliação. O acesso às informações das clínicas e hospitais possibilitará maior robustez aos indicadores da doença, propiciando a elaboração de políticas públicas condizentes com a realidade da LVC em Uruguaiana.

PALAVRAS-CHAVE: Leishmaniose; Saúde Única; Sistemas de Informação em Saúde

INTRODUCTION

Leishmaniases are parasitic diseases caused by protozoa of the genus *Leishmania* transmitted to people and animals by the bite of infected female phlebotomine bugs. Human visceral leishmaniasis (HVL) is the most serious form of the disease and is fatal if left untreated in 95% of cases. It is estimated that between 50,000 and 90,000 cases occur worldwide every year. The most affected areas are Brazil, East India, and Africa[1]. In 2008, Rio Grande do Sul (RS) became an area of HVL transmission with the occurrence of autochthonous canine (2008) and human (2009) cases. Uruguaiana (RS) is one of the five municipalities in Rio Grande do Sul with autochthonous cases of HVL[2]. From 2009 to 2023, four cases of HVL were confirmed in Uruguaiana (July 2011, October 2016, February 2017, and January 2023). Despite the small number of human cases, there are numerous cases of canine visceral leishmaniasis (CVL) in the municipality. In the period between 2010 and 2022, of the total of 2,720 samples collected from dogs requested by spontaneous demand to the Uruguaiana Environmental Health Surveillance (VIAM), 1,589 (58.42%) were positive for CVL, by immunochromatographic rapid test and subsequent confirmation by ELISA technique[3].

Public policies for the control of HVL have not been effective in containing the spread of the disease in Brazil in recent years. Although the incidence decreased between 2018 and 2021, the lethality rate and geographical expansion increased[4,5]. The severity of the problem demands the development of new surveillance strategies aimed at demarcating areas with a higher risk of transmission, as well as evaluating the effectiveness of prevention and control measures in the urban environment[6,7]. The search for a better understanding of the main determinants associated with the disease, the affected population and the environment will help in the control and prevention of this disease, and will also serve as a strategic control model for other diseases[8]. In order to better tackle challenges of this magnitude, new risk-based surveillance strategies must be developed, considering not only human beings as sentinels of the disease and adding new tools for the early detection of cases before there is an opportunity for greater dissemination and perpetuation of the disease in the population. From this perspective, professionals working in the areas of human, animal and environmental health should prioritize joint action to control the risk of the disease. The One Health concept recognizes that human health is closely linked to the health of animals and the environment. For the integration of disease surveillance in humans, animals and the environment to be effective in detecting the occurrence of diseases in populations at an early stage, there is a need for support in the integration of data to determine factors that promote the emergence of disease, as well as interventions to prevent its occurrence on a regional scale[9].

Dogs are the main domestic reservoirs of HVL and, for this reason, control of the canine reservoir is one of the components of the Ministry of Health's technical standards for surveillance and control of the disease[10]. However, it is possible that cases of canine leishmaniasis are underreported, due to the lack of active search for dogs by serological surveys, as well as poor passive surveillance, without the involvement of private veterinary units.[11,12]

Uruguaiana is characterized by a high occurrence of canine cases, monitored by VIAM via spontaneous demand from the public, analyzed monthly via tables and graphs in a descriptive manner. However, many cases are confirmed in clinics and hospitals, without this information being forwarded to VIAM. The incompleteness of the data prevents the real impact of the disease from being known, which weakens the planning of effective prevention and control actions[12,13].

Advances in research and disease control require collaboration of information between different areas such as clinics, infectology, and epidemiology[14]. Public and private organizations use systems with a large volume of data which are often poorly used by managers, as they are developed by different teams without being integrated. In addition, the emergence of new development and analysis platforms requires systems to be adapted to technological innovations[15].

The World Health Organization considers mobile technologies to be an important resource for the health sector due to their ease of use, wide reach, and broad acceptance[16]. In some low-income countries, mobile telephony is more constantly and reliably accessible than electricity and drinking water[17]. New health information technologies (*eHealth*), especially mobile health (*mHealth*), can play a key role in realizing this potential in various health sectors, including disease surveillance, increasing global health security. The growing use of the internet and mobile phones has led to new approaches to obtaining health information, such as collecting information and data on indicators directly from the affected population or other stakeholders[16]. The new information and communication technologies

(ICT) can be of great value for the prevention and control of diseases, especially for Neglected Tropical Diseases (NTDs) which are more prevalent in tropical areas where poor communities are more affected[18]. Considering this context, professors from the Graduate Programs in Animal Science and Software Engineering at the Federal University of Pampa (Unipampa) and VIAM from the Uruguaiana Health Department concluded that the development of an integrative system of public and private domain information to carry out strategic epidemiological analyses of VL in the municipalities of the Western Border of Rio Grande do Sul would be of great help in better understanding the highly complex scenarios related to VL.

The aim of this article was to present the development stages of the PampaCare LVC mobile interface, part of the PampaCare platform, with the aim of increasing the epidemiological support needed to develop more assertive surveillance actions and public health policies for LVC.

METHOD

Design of PampaCare LVC

PampaCare LVC was developed as an interdisciplinary proposal, involving the areas of Computer Science and Health, with the aim of migrating from a legacy system based on manual physical forms and Excel tables to an automated tool, as well as defining the requirements of the new information system. A legacy system, although it was developed in the past and without the use of modern computer engineering techniques, has important information for the institution in which it operates[19]. The app development process began in March 2020, motivated by the demand for innovative projects to support the fight against COVID-19 (INOVA-RS). Considering the relevance of VL for Uruguaiana and the Western Border region of Rio Grande do Sul, the Unipampa professors presented the proposal to VIAM, which, at the time, was using a legacy system to record data on CVL in the municipality and was already looking to improve the system for reporting and analyzing cases.

Development of PampaCare LVC

The development of PampaCare LVC involved collecting and analyzing requirements, specifying use cases, and using modern technologies such as Flutter and Firebase. The minimum viable product (MVP) version was made available to Environmental Health Surveillance in April 2023, and the final version will be released in August of the same year.

Collecting and analyzing requirements

The process of gathering requirements requires the use of techniques that allow an understanding of the specific needs and expectations of users and other stakeholders involved in the project[20]. In PampaCare LVC, the techniques of interviews with stakeholders (VIAM of Uruguaiana) and (developers, professors, and students from the Software Engineering course and the Veterinary Medicine course at Unipampa) and analysis of documents and records (investigation form used by the State Health Department) were used to extract the requirements. Additional meetings were held to supplement the data extracted from the spreadsheets and to identify and add new categories to the information system.

The tool called MosCoW[21], which helps to order the activities of a project according to their relevance, was used to establish the priority requirements of PampaCare LVC.

Specification of use cases

In the specification of the use cases, the main requirements of the system were detailed and an extended description of the use cases was created, which includes concepts about how the screen should work and its operating conditions, based on the requirements established[22].

Architecture definition

The architecture project takes place after the requirements have been elicited and the use cases have been analyzed. During this stage, the structure of the system is defined and how it will be organized[19]. It is more appropriate to define the structure of the application during the initial stages of the work in order to identify and deal with risks, since the more advanced the project is, the greater the costs of modifications[19]. The PampaCare LVC project opted for a clean, organized architecture separated into modules, ideal for keeping the code clean and easy to maintain.

Flutter and Firebase technologies

Flutter and Firebase technologies were used to develop PampaCare LVC. Flutter is a framework developed by Google for creating multi-platform mobile applications[23]. Firebase is a mobile application development platform that offers features such as user authentication, real-time data storage and data analysis[24].

The backend, i.e., the programming for the internal part of the application, was built using Firebase's authentication and cloud firestore functions[24], which provide Firebase's integrated authentication, user management and cloud storage services, respectively, allowing hierarchical document data to be stored and managed in real time.

For the application's frontend layer, i.e., its front part with which users can interact, a solution was developed for smartphones that will be made available for Android and IOS using the Flutter framework in the development process, which made it faster and more efficient to generate the expected result. This framework makes communication with the database easier, allowing developers to integrate the application with various database options, such as Firebase. Flutter uses widgets as building blocks to create the application's user interface for listing and registering dog guardians. Widgets in Flutter are used to create and manage visual elements such as buttons, input fields and lists[25]. Flutter offers a wide range of native widgets, compatible with Android and iOS, allowing developers to

create applications with the same look and user experience on both platforms. It also makes it possible to create customized widgets, which can be adjusted to meet the specific needs of the application[25].

Documentation

Documentation is the stage of application development responsible for recording in text the essential information about a system[19]. The documents are sent to the software engineering and testing teams and to other users. The application documentation process begins before implementation, for example with the requirements and use case documents.

Implementation

Implementation is the stage in which the system is coded from the computational description of the design phase, enabling the generation of executable code for the project[19]. The PampaCare LVC implementation process was carried out in two stages. In the first, the requirements of greatest importance and priority were implemented to ensure that the MVP version of the application was implemented and used by the interested parties. In the second, the requirements that added value and further complemented the application were added.

User experience evaluation

The user experience and usability guidelines for agile project (UXUG-AP) technique[26] was used to carry out a user experience evaluation. In this technique, the evaluation was divided into 11 categories, with their respective subcategories, based on guidelines that deal with usability and user experience in projects.

Support

Support, i.e., assistance with the infrastructure of the software, hardware, and network systems in order to prevent, detect, and correct errors, will be provided by a startup company. The service provided by this startup will allow the application to be improved with quality by carrying out the necessary maintenance and updates, as well as supporting stakeholders such as the Municipal Health Department and veterinary clinics in using the application.

RESULTS

PampaCare LVC requirements

In the first stage of the creation process, 22 requirements were defined, which were then translated into functionalities for the application. Chart 1 shows the main requirements identified in the requirements collection and analysis stage and highlighted for their functionality and importance for solving the problem (developing an application for the control and prevention of CVL), using the MosCoW tool[21].

The first requirement, for example, deals with user authentication, which is done by registering via e-mail and password. Using the Firebase authentication service allows this requirement to be implemented quickly, as well as easily adding new forms of login in the future. Along with the authentication requirement, the application has control over registration ownership and user levels. The access rules for each user level are shown in Chart 2 by means of use cases.

PampaCare LVC data

PampaCare LVC's data is stored and managed in Cloud Firestore, a NoSQL database provided by Firebase that allows data to be stored and synchronized in real time. Cloud Firestore is highly scalable and flexible, allowing data to be stored and accessed quickly and efficiently, as well as offering advanced query and security features. It also allows you to define security rules that control access to the data, ensuring that authorized users can read and write the information. Figure 1 shows the organization of the application's non-relational database.

PampaCare LVC screens

Figure 2 shows the following PampaCare LVC screens: home screen (A), the drawer for accessing the application screens (B) and the "Owners" section (C, D). User authentication, developed with Firebase authentication, uses email and password. In the "Owners" section it is possible to register, edit, list, and delete, which are essential for the application to function correctly. Information on the owner's name, address, telephone number, and e-mail address, as well as the date of the notification, is recorded in this section. Figure 2 (D) shows the geolocation functionality with which it is possible to collect the current location via the mobile device's own GPS and add it directly to the register, as well as allowing manual registration if necessary.

Chart 1. PampaCare LVC software requirements.

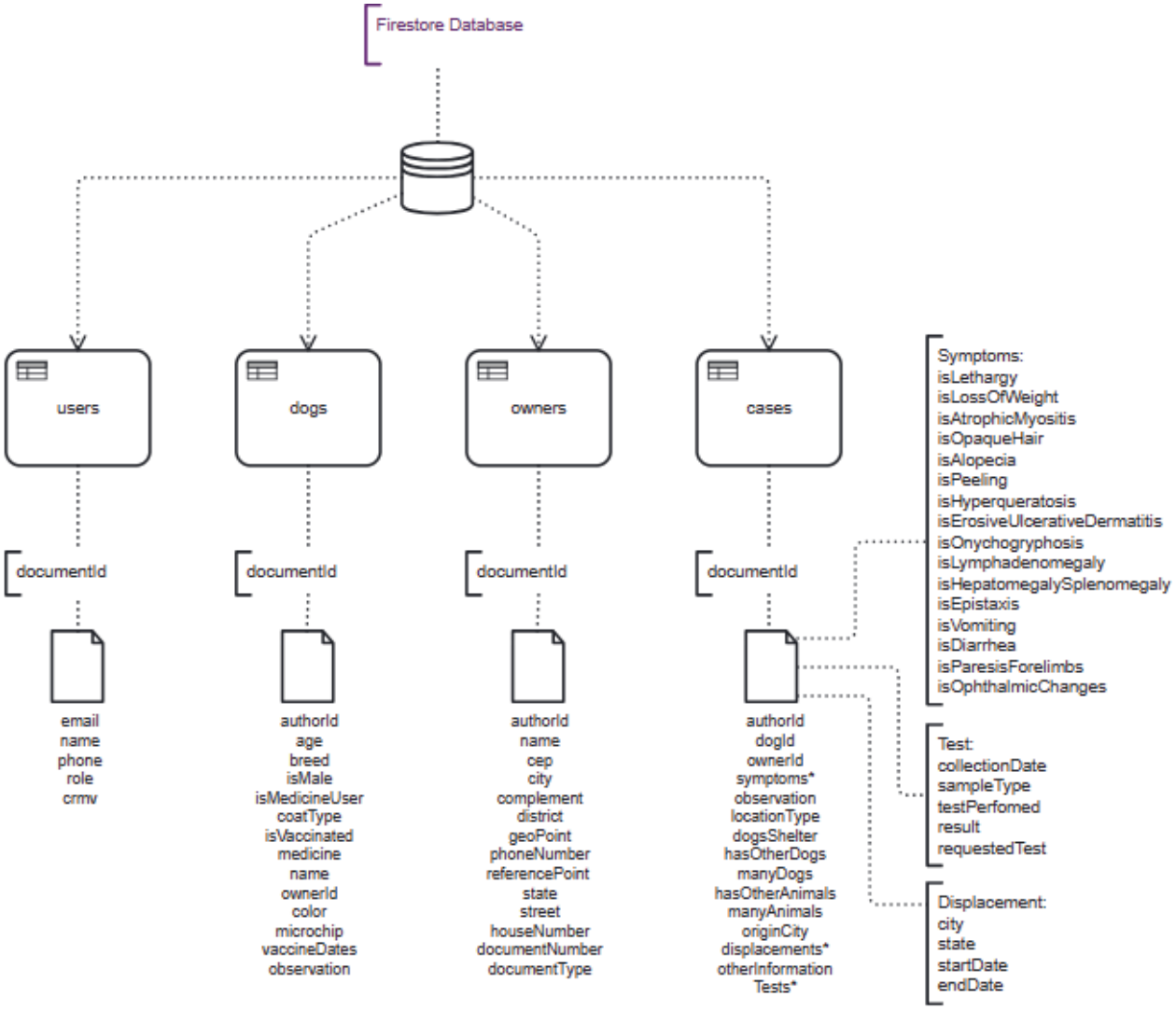
Requirements	Description
RQ01	The system must have role-based user authentication. Each role will have a specific level of access to the data.
RQ07	The logged-in user must have access to edit their user data and delete their account.
RQ12	Owner registration must include geolocation information.
RQ13	The list of owners must allow redirection to a map service.
RQ15	The application should have ways of creating case notifications, as well as editing and deleting existing ones.
RQ16	The application must have ways of inserting tests/examinations into case notification records.
RQ22	The application must be compatible with Android and IOS.

Source: Prepared by the authors, 2023.

Chart 2. Use cases showing the roles and functionalities performed by users.

Operation	Administrator	Researcher	Student
View	Yes (all data)	Yes (only their own data)	Yes (all data)
Register	Yes (all data)	Yes (only their own data)	No
Update	Yes (all data)	Yes (only their own data)	No
Delete	Yes (all data)	Yes (only their own data)	No

Source: Prepared by the authors, 2023.



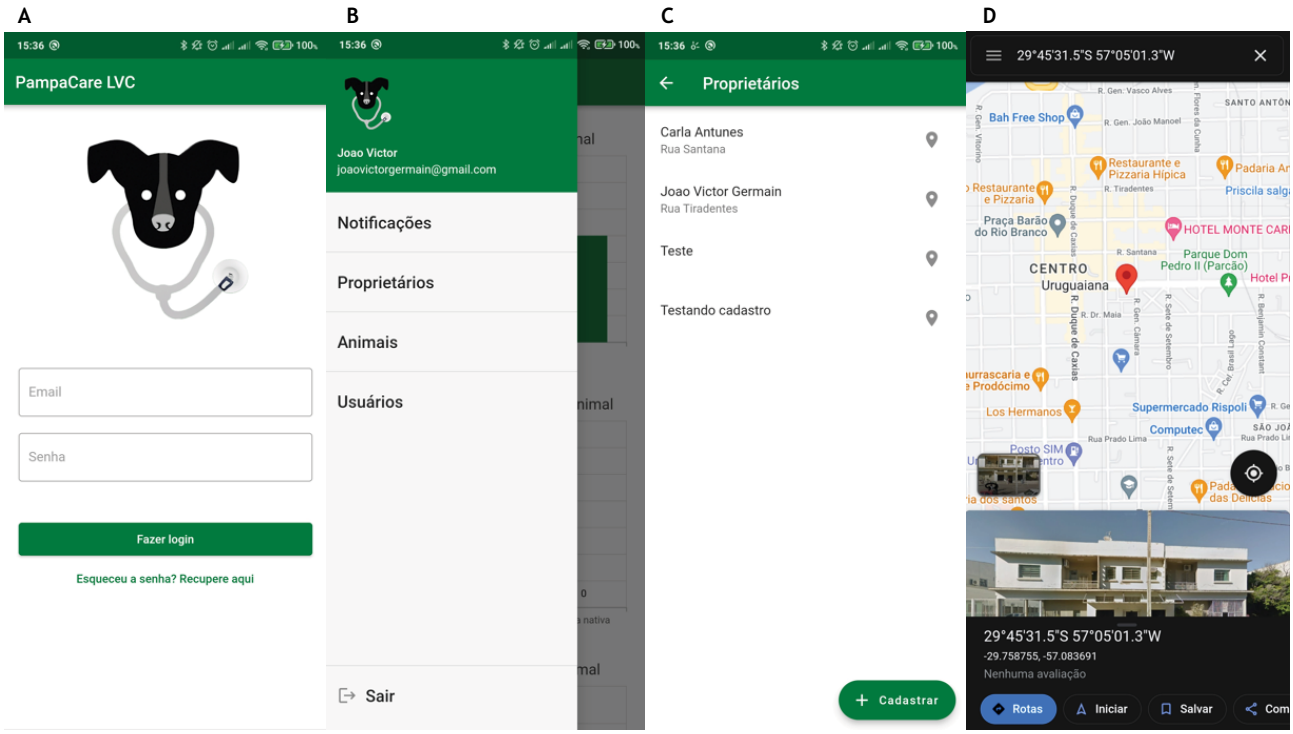
Source: Prepared by the authors, 2023.

Figure 1. Document diagram with structure for NoSQL.

The application also offers an additional feature that allows the user to view the location of the animal's owner and the suspected case on the map, via a redirect button to Google Maps.

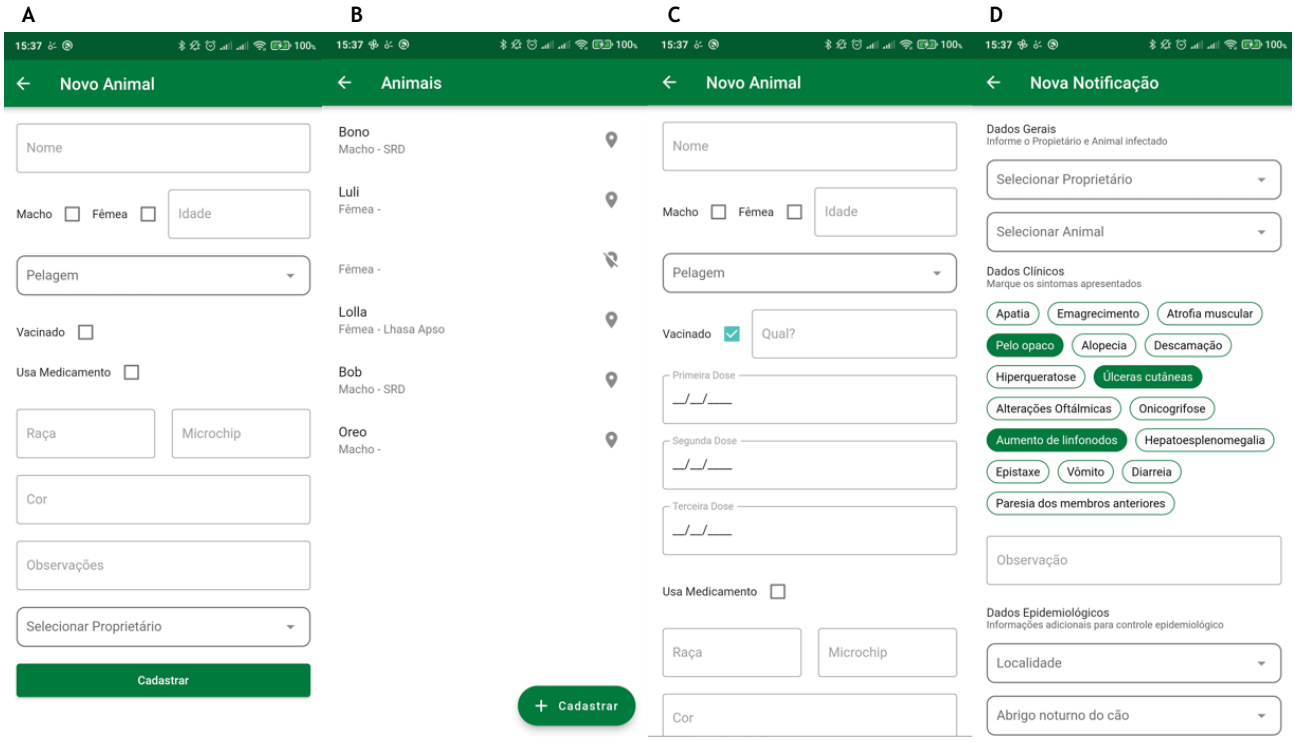
Figure 3 shows the animal management flow. In this section, you can see the notification (A), registration (B and C) and animal clinical signs (D) screens. The following animal data can be recorded: age, gender, breed, coat color, vaccination status, medication used, clinical signs, and laboratory data. The application offers a list of clinical signs that can be selected by the user, as well as the option other(s) for those signs that do not appear on the list.

The other two sections of the app are: Notifications and Users. In the Notifications section, the user can manage registered notifications and register new ones. In the Users section, the user management flow is carried out, which can be focused on the user's own account or the account of a third party from the administrator's perspective.



Source: Prepared by the authors, 2023.

Figure 2. Home screen (A), Drawer (B), and "Owners" section of PampaCare LVC (C and D).



Source: Prepared by the authors, 2023.

Figure 3. "Animals" section: Notifications (A); Registration (B, C); Clinical Signs (D).

User experience evaluation

The self-assessment process showed that the app met 76% of the subcategories, i.e., it performed satisfactorily in terms of user experience and usability (Chart 3). After the updates, the aim is to achieve 92% coverage, so that only accessibility remains to be implemented in the future.

DISCUSSION

PampaCare LVC is the result of multidisciplinary work to create one of the interfaces of a distributed information system with structured and integrated data in real time, aimed at monitoring and analyzing information related to One Health to strengthen the surveillance, prevention and control of VL.

PampaCare LVC was designed to strengthen intersectorality and collaboration between the public and private sectors, using computer tools to generate a new view of CVL by combining the efforts of professionals from different areas and backgrounds to communicate indicators and reports to the population. The integration of human, animal, and environmental data will speed up the notification and confirmation process for the VIAM sectors since the increase in canine cases precedes the increase in human cases[27].

Chart 3. User experience evaluation using the UXUG-AP technique.

Category	Sub-categories	It has
Requirements	Exchange of information - Team/customer	Yes
	Interviews and workshops	Yes
	Key requirements	Yes
Understanding user needs	Beginners and experts	Yes
	Children, young people, adults, and the elderly	Yes
	Lay people, academics, and professionals	Yes
Accessibility	Visually impaired I	No
	Visually impaired II	No
Ease of use	Location	Yes
Informative feedback	Warning message and confirmation	No
	Error message	No
	Loading components	Yes
	Titles and links	Yes
Error prevention	Mandatory fields	No
	Limiting fields	No
	Self-explanatory presentation	Yes
Grouping information	Independence of information	Yes
	Modularization of information	Yes
Sequence of actions	Organization of sequential actions	Yes
	Behavior of sequential actions	Yes
Feelings of belonging	Emotional connectivity	Yes
Degree of importance	Information position	Yes
	Relevant terms	Yes
Privacy	Information control	Yes
	Passwords	Yes

Source: Prepared by the authors, 2023.

Other researchers have focused their research on the development and implementation of ICT in health-related activities. In the field of NTDs, there are experiences of using ICT to prevent and control these diseases. Torres[28] developed an open-source tool, Rega DB leishmaniose, which allows the creation of a database of multiple types to be used in complex analyses using Big Data techniques, supporting new studies into tegumentary leishmaniasis. Silva et al.[29] developed a smartphone application called Leishcare to help health professionals diagnose and manage leishmaniasis in endemic areas. iChagas, a mobile app created by the Drugs for Neglected Diseases Initiative (DNDi), provides health professionals with up-to-date information on Chagas disease[30].

Regarding CVL, Vasconcellos et al.[31] developed C7-LVC, characterized by a system capable of storing data on the notification of the canine disease, in Santa Maria (RS). Lisboa[32], considering that there is no real-time surveillance system for reporting CVL in Brazil and that information on infected dogs is incomplete or undersized, evaluated the use of the surveillance and control application (ViconSaga Mobile) and concluded that the tool contributes to obtaining centralized data on CVL. C7-LVC and ViconSaga are two examples of the use of information technology to optimize CVL control, and both applications were developed based on existing software. PampaCare LVC, with a similar proposal, used the Firebase and Flutter platforms, aiming, in addition to solving the notification problem itself, to present a good user experience through modern and intuitive interfaces, making the application user-friendly.

In addition to VL, studies have highlighted the positive aspects of the canine species as a sentinel for other human diseases[33,34,35]. Dogs are ubiquitous in the domestic environment, can be stray or semi-domesticated and are exposed to multiple pathogens. In addition, stray dogs share space with other animal species and can serve as a link between wild animals, synanthropic animals, and humans[36]. The PampaCare CVL model can be easily adapted to other diseases that share determinants related to canine cases, serving as a source for creating vulnerability indicators for other relevant diseases.

The high popularity of cell phone use, coupled with easy access to information and the large number of users connected at the same time, justifies the use of mobile applications in the health field. In addition, these tools facilitate rapid communication within teams, which favors multi-professional involvement[37]. However, there are difficulties for health professionals in adhering to the use of the app, mainly related to resistance to the use of new technologies, such as digital information and communication tools[30]. In the case of CVL, the lack of an

established compulsory notification protocol, with the planning of actions and deadlines for investigation and closure of the suspected case, as well as the definition of which body will receive the notification of cases, makes it difficult for veterinarians to adhere to control programs[38]. Therefore, the success of a health-specific mobile application depends on correctly interpreting the needs of users and implementing an adequate support infrastructure for professionals, motivating them to use the tool.

There are major challenges in carrying out maintenance and upgrades on legacy software, mainly due to the lack of documentation and the need to develop new features and improve old ones[39]. However, by using software engineering processes, with the definition of clear objectives to offer agility and efficiency in the adoption of CVL prevention and control actions, it was possible to create a simple, low-cost and maintenance solution that fits the needs, capable of assisting in the planning of actions that add health and quality of life to dogs and their guardians.

With its main features being the notification and geolocation of suspected cases, with the recording and storage of epidemiologically relevant information that allows for the generation of reports and analysis, PampaCare LVC will help to reduce the underreporting of cases and plan control actions that are compatible with the real health status of the disease. The application has the functionality of a data repository with epidemiological information in the form of tables and graphs. As this information is confidential, it will not follow the open-source license and can only be accessed with the administrator's permission. The application's functionality of having access levels guarantees the confidentiality of the data, while at the same time making certain functions available to all users. The geolocation feature is useful for setting up alerts regarding the epidemiological situation of neighborhoods, helping to carry out territorial-based environmental surveillance for the control and prevention of CVL in an assertive manner.

As future work, the aim is to carry out a complete roll-out of the application for widespread use (veterinary practices, clinics, and hospitals). The MVP version will be made available in April in a relevant environment, and the final version with all the features is expected to be launched by the end of August in a definitive environment. The functionalities of the final version include offline operation and epidemiological reports, which will be crucial for field surveys in places without a stable internet network and for analyzing consolidated data later on. In addition, features such as PDF export will allow data to be sent to cities that don't use the application. The implementation process and support for the application will be carried out by a startup, allowing it to be used by the Uruguaiana Health Department, hospitals, and veterinary clinics, with rapid correction in the event of any technical or operational problems.

CONCLUSIONS

PampaCare LVC is the result of a successful multidisciplinary development process between the areas of health and computer engineering, which was able to deliver a LVC notification and data management application aimed at strengthening disease surveillance, prevention, and control actions. The application met 76% of the subcategories assessed using the self-assessment technique, i.e., it performed satisfactorily in terms of user experience and usability. After the updates, the aim is to achieve 92% coverage of the subcategories included in the evaluation tool. The next stages of the study will be to validate the application with users and fully implement it for widespread use by VIAM Uruguaiana and private veterinary establishments.

Access to new information obtained from various sources will make it possible to make the indicators of the occurrence of the disease more robust, enabling public policies to be drawn up that are more in line with the reality of CVL in the municipality of Uruguaiana. Despite being a necessary and promising initiative, the successful implementation of the application will require the awareness and collaboration of the professionals who work in CVL control. VIAM Uruguaiana, the app's administrator, must ensure that PampaCare LVC is publicized and maintained, as well as providing advice to users. Those responsible for private veterinary establishments are responsible for ensuring that this new tool is widely used and that the app is correctly and constantly fed with information on CVL, understanding that without collaborative, multi-sectoral, and transdisciplinary actions and approaches, it will not be possible to stop the advance of CVL and HVL in the state of RS.

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Authors' Contribution

Massial LI, Basso FP, Pellegrini DCP - Conception, planning (study design), analysis, data interpretation, and writing of the work. Germain JVG - Planning (study design), analysis, data interpretation, and writing of the work. Farias JB - Planning (study design). All the authors approved the final version of the work.

Conflict of Interest

The authors inform that there is no potential conflict of interest with peers and institutions, political or financial, in this study.