DeclaraRS: A multi-platform approach to herd declaration by rural producers in the context of Agriculture 4.0

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Abstract

This article presents DeclaraRS, a multi-platform approach to herd declaration by rural producers in the state of Rio Grande do Sul, Brazil. DeclaraRS uses a hybrid web architecture, allowing rural producers to declare herds online or offline, anywhere and anytime. DeclaraRS transforms herd declaration from a time-consuming and error-prone task into a (semi-)automated and less bureaucratic task that generates strategic information. By automating the declaration, government technicians end up performing fewer manual and tedious tasks, while increasing educational tasks, aiming at productivity gains on rural properties. Managers benefit from using up-to-date information about herds, helping to make strategic decisions considering public policies. DeclaraRS was evaluated by developing a functional prototype, the application of the TAM questionnaire to assess acceptance, and interviews with rural producers, agricultural technicians, and public managers. The results are encouraging and show the potential use of the proposed approach in a real context.

Keywords: Agriculture 4.0, Mobile application, Layer-based Architecture

1. Introduction

The adoption of digital technologies in agribusiness plays a fundamental role in the economy of emerging countries such as Brazil [1]. In this context, livestock is an important part of agribusiness, involving the creation of different types of animals, including cattle, goats, and horses, among others. Usually, rural producers are responsible for raising and maintaining these animals on rural properties. These animals form the herd of a certain region. An example of a region would be the state of Rio Grande do Sul, which is located in the southern region of Brazil and has 11.3 million inhabitants. An ever-present concern of public managers is the control and management of these herds. In the Rio Grande do Sul, for example, public managers face the challenge of managing herds spread across several rural properties in 497 municipalities. Although essential for sanitary control and strategic decision-making by public managers, the management of these herds ends up being a challenging, time-consuming, and error-prone task.

In the context of Agriculture 4.0, the use of sensors, smartphones, and multi-platform Web applications is encouraged, aiming to bring technology to the reality of rural producers. Lu and Young (2020) [2] highlight the importance of using computer vision techniques in the context of precision agriculture. Zhai (2020) [3] explores the challenges of implementing decision support systems in agriculture 4.0. Bischoff and Farias (2021) [4] present trends that need to be explored in agriculture, mainly through the use of the Internet of Things and process automation. In addition, Quispe and Eler (2018) [5] highlight initiatives to improve the services offered to society through process automation and interoperability. In this sense, public managers and rural producers need to improve practices and processes through the adoption of emerging technologies found in Agriculture 4.0. For example, in the Rio Grande do Sul, public managers must carry out the sanitary control of herds present in their states and municipalities. For this, rural producers must declare their herds. Unfortunately, the declaration is made by filling in paper forms manually, generating unstructured data, and impairing the effective use for decision-making by public managers.

Previous works have tried to explore some facets of this problem. Pádua (2015) [6] developed an application for herd management, but it does not deal with regulatory aspects with the government. Alvarenga (2014) [7] proposed an application for herd management but limited to the bovine species. Trigo *et al.* (2018) [8] developed a mobile application for herd management and registration, with regulatory aspects, but limited to bovine and buffalo species. Tonisso *et al.* (2016) [9] developed a mobile application for herd management in dairy farming. Kuhn (2018) [10] proposed a mobile application for agricultural management but with a focus on planting activity. Lopes *et al.* (2000) [11] developed a herd registration and management system, but focused on bovine species and using Desktop technology. Salin (2006) [12] proposed the development of a herd management and control system, but it applies only to the goat species.

⋆Fully documented templates are available in the elsarticle package on CTAN.

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This article, therefore, presents DeclaraRS, a multi-platform approach to herd declaration by rural producers in the state of Rio Grande do Sul, Brazil. DeclaraRS uses a hybrid Web architecture, allowing rural producers to declare herds online or offline, anywhere and anytime, bringing ubiquitous computing concepts to rural producers. DeclaraRS transforms herd declaration from a time-consuming and error-prone task into a (semi-)automated and less bureaucratic task that generates strategic information. We conjecture that the declaration made manually using paper represents a step backward in the context of Agriculture 4.0. The manual declaration makes the declaration process time-consuming, generates unstructured data, and does not exploit the potential of smartphones already widely disseminated among rural producers today. By automating the declaration, government technicians end up performing fewer manual tasks, while increasing educational tasks, aiming at productivity gains on rural properties. Managers benefit from the use of up-to-date information about the herds, helping to make strategic decisions considering public policies. DeclaraRS was evaluated through the development of a functional prototype, the application of the TAM questionnaire to assess acceptance, and interviews with rural producers, agricultural technicians, and public managers. The results were encouraging and show rural producers'potential use of the proposed approach for herd declaration in a real-world context.

This work is organized as follows. Section 2 presents the theoretical background. Section 3 reviews related work. Section 4 describes the proposed approach. Section 5 describes how the proposed approach was evaluated. Section 6 draws some conclusions and points out upcoming works.

2. Background

This section presents the fundamental concepts to understand the proposed approach. Section 2.1 introduces the concept of herd declaration and Section 2.2 explains the fundamentals of multi-platform software architecture.

2.1. Herd Declaration

The herd declaration consists of an annual activity and has a regulatory and informative function by recording the balance of herds in the Rio Grande do Sul. The declaration consists of two steps. In the first stage, the rural producer goes to the veterinary inspection of the Secretary of Agriculture, Livestock and Rural Development (SALRD) — agency of the State of Rio Grande do Sul responsible for regulating and managing agricultural activities, as well as requiring veterinary inspections in the municipalities of the state of Rio Grande do Sul. In the inspectorate, the rural producer manually fills in a paper declaration form, informing the number of animals per species, animal gender, and the location of his rural property. In the second stage, a health inspector reads the declarations and manually registers the information on the forms in the Agricultural Defense System. Rural producers and rural properties must be duly registered in the Agricultural Defense System; otherwise, they cannot carry out any activity in the context of agribusiness.

2.2. Multi-platform Application Architecture

The architecture for developing mobile applications usually consists of two parts (back-end and front-end), which may use different technologies and architectures. The back-end of the proposed approach is responsible for integrating with external systems by requiring and sending data regarding the herd declarations. Communication occurs through Web services, using the REST architecture and following a set of principles and architectural standards of HTTP communication protocols. All manipulated data is represented in JSON (JavaScript Object Notation).

In the development of the front-end, we created some forms of access to information through the use of different devices used by users. As the practicality in the construction and maintenance of the application is of fundamental importance, the Web application architecture, using Progressive Web Application (PWA), emerges as a way to meet the needs. In this way, it becomes unique to build the technological solution, and the user can even add the application on their mobile devices and work offline.

3. Related work

Declaration of herds is an ever-present topic on the agenda of government agents in the context of Agriculture 4.0. Consequently, studies strictly related to the topic have gained space. In this sense, we surveyed the current literature to identify works similar to the theme explored in our article. For this, the terms "Application for agriculture" and "Herd management" were applied to two libraries: Google Scholar [1] and Scielo[2]. In total, seven papers were selected, which are analyzed and reported below.

3.1. Analysis of Related Works

Pádua (2015) [6]. The author developed software aimed at serving the small rural producer through the activity of registration and management of livestock herds management. The application includes the registration of several species, covering the context of the application. With a focus on assisting the management of the herd, aiming to make the activity more profitable for the rural producer. There is no evidence that it enables integration with public programs. Developed for the Android platform, the application is restricted to users of a single operating system, unlike the proposal of this work, which uses the web architecture, which makes it possible to access the application on devices of different operating systems.

Alvarenga (2014) [7]. The study developed two applications aimed at the registration and management of the bovine species. For the development of one of the applications, web

[1]Google Scholar: https://scholar.google.com/

[2]Scielo: https://scielo.org/

architecture was used. The second application was developed for mobile devices, using the Android architecture and thus addressing the multiplatform aspects. The purpose of the applications is to contribute to the management of the cattle breeding activity, through the control of production activities. Different from the proposal of this work, which develops through the declaratory context of herds, containing different animal species.

Trigo *et al.* (2018) [8]. Through the use of traceability technology, the author developed a mobile application on Android and iOS platforms. Presenting a solution for cattle herd management. Intended exclusively for rearing beef cattle. At the end of the process, the application integrates with the national bovine rastreability system. Even though it resembles the proposal of the present work concerning the declaration of herd and integration with programs of public agencies, it differs by being limited to one kind of livestock.

Tonisso *et al.* (2016) [9]. The study aimed to develop a mobile application, on the Android platform, to assist in the activity of milk production livestock. Intended to assist in the daily activities of the rural producer. Provides management tools to increase the productivity of the property. The application analyzed, despite carrying out the management and control of herds, differs from the proposal of the present work when it is intended only for dairy activity, delimiting its access to a mobile platform and not presenting integration between systems.

Kuhn (2018) [10]. The work proposes the development of a mobile application, for agricultural management, designing the application to aid activities performed by the rural producer. With this, a register of planted crops was developed, carrying out control of plant production and stocks of Inputs. The work analyzed performs the registration and management of rural properties but it cannot be applied to livestock activity. To be a mobile platform application, it was developed for the Android operating system, limiting the multiplatform approach.

Lopes *et al.* (2000) [11]. This work developed a computational system focused on the sizing and control of cattle herds, aiming to assist the rural producer in the management of herds in different livestock activities. In this way, a desktop system was created, without the use of integration with the internet. The analyzed system differs from the DeclaraRS when performing the herd control only of the bovine species and does not apply to multiplatform aspects.

Salin (2006) [12]. The work developed software, whose objective is linked to the management of goat herds. It presents tools for different purposes of livestock activity, from the breeding factors. When comparing the application analyzed with the proposal of the present work, it is verified that, despite performing herd management, it comprises only one species. In addition, the developed system runs only on one platform.

3.2. Comparative Analysis and Research Opportunities

We defined five Comparison Criteria (CC) to identify similarities and differences between the proposed work and the selected literature. We adopted this strategy to analyze related studies based on objective criteria for two reasons. First, this strategy has been shown by previous studies [13, 14, 15, 16] to be useful in pinpointing improvements and research opportunities that are worth investigating. Second, instead of analyzing the current literature subjectively, we use objective criteria. The criteria are presented as follows:

- **Application context (CC1):** works that support the registration and management of herds in the context of agricultural practices, and that enable the evolutionary monitoring of animals.
- **Regulatory Purpose (CC2):** studies the purpose of applications, contemplating the regularization of regulations or laws that govern the registration and updating of properties and herds. The criterion allows the application to be a facilitating means in the regularization of livestock activity with public agencies.
- **Animal species addressed (CC3):** compares the breadth and diversification of animal species addressed by work related to animal herd breeding. The context of exploitation of agriculture for different animal species, helping to the purpose of herd generation.
- **Integration with public programs (CC4):** in this criterion, there is the possibility of integrating the applications with the public data network and/or with programs regulated by public entities.
- **Multiplatform aspects (CC5):** For the application to have a greater scope of execution and availability to the rural producer, it is determined that one of the aspects to be considered as implementation differentials is the diversity that the applications present when being executed on different devices and platforms.

Table 1: Comparative analysis of related works

Related work	Comparison criteria				
	CC01	CC02	CC03	CC04	CC05
Proposed work	●	●	●	●	●
Pádua (2015) [6]	●	○	●	○	◐
Alvarenga (2014) [7]	●	○	◐	○	◐
Trigo *et al.* (2018) [8]	●	●	○	◐	●
Tonisso *et al.* (2016) [9]	○	○	◐	○	◐
Kuhn (2018) [10]	○	○	○	○	◐
Lopes *et al.* (2000) [11]	●	○	◐	○	○
Salin (2006) [12]	●	○	◐	○	○

● Completely supports ◐ Partially supports ○ Not supports

Research opportunity. Table 1 shows the analysis of the related studies and the comparison criteria created, contrasting with the work proposed. With the comparative result, it is possible to observe the following research opportunities: (1) the intention to integrate with the public network programs and the purpose of regulating the rural producer with the public agencies; (2) the works analyzed were limited to the control and registration of some animal species, not

performing the exploitation of other livestock herd crops; (3) the availability of access to applications on different devices were limited, mainly, to the Android platform, not covering other possibilities of multiplatform access. Therefore, the proposed work contemplates all the criteria addressed, aiming at the development and aggregating innovation in the processes, which are fundamental for the registration of herds and the regulation of livestock activity in southern Brazil.

4. Proposed approach

This section introduces DeclaraRS, a multi-platform approach to livestock declaration by farmers. Section 4.1 presents a process overview, introducing the implemented business process in stages. Section 4.2 presents the conceptual model, detailing the entities and relationships. Section 4.3 presents the proposed architecture in the application development.

4.1. Process Overview

Figure 1 demonstrates an overview of the business modeling and activity flow of the herd declaration process, proposed in the development of the application, addressing four steps: Authentication, Herd Entry, Data Transmission, and Proof Emission. The steps are detailed below.

- **Step 1: Authentication.** To perform the access, the user must first go through the authentication step in the application. Initially, the user must enter his credentials, so that, next, the application validates the data entered, searching in the local or external database. If the authentication is successful, the user can proceed with using the application. When validation is unsuccessful, the user can retry or exit the application

- **Step 2: Flock launch.** This step is the flow of the application's herd declaration. Once authenticated, the user can view and interact with the farms and agribusinesses to which he is connected. With the agribusiness selected, the user can perform the herd declaration linked to the livestock activity in the agribusiness. Once a declaration is finalized, the user proceeds to the data transmission stage, where the information entered is processed.After finishing the declaratory process, the user can choose to exit the application or return to the agribusiness step, enabling the user to enter other herd declarations in the same session.

- **Step 3: Data transmission.** This step manage, store, and transmit the data entered. When finishing the herd declaration, the system moves to the data transmission stage. Initially, the information transmitted is stored in the application's local database, so that it can continue the activity of transmitting the data to the external system. When there is an Internet connection, the application automatically transmits the declared data. Once the transmission of the declaration is successful, the application sends a message to the proof issuance step, continuing the declarative process. In case the data transmission does not occur, the declaration is stored with the pending status and, thus, the data transmission stage is closed, returning to the flock launching stage.

- **Step 4: Issuance of declaration proof.** In this step, the declaration proof is generated if the transmission is successful. After transmitting the herd declaration, the voucher issuance stage receives the notification, starting the generation of the annual herd declaration issuance proof, containing the informed data. It becomes available to the rural producer the guarantee of regularity with the secretary of agriculture. At the end of the proof issue stage, the application returns to the flock entry stage, continuing the process.

4.2. Conceptual Model

Figure 2 shows the conceptual model of the herd declaration application, where the entities and the relationships between them are expressed. For the operation and example of the proposed approach, the model includes eight of the main entities, which are detailed below.

- **Authentication:** Entity responsible for obtaining and storing the login, password, and *token* data (if any), of the user to use the application. Through authentication, it obtains the return of the data entered, validating the user's access to the application.

- **User:** This entity, the rural producer user data are assigned, containing information such as name, address, CPF, or CNPJ. Contains the personal data of the user already authenticated in the application.

- **Property:** It contains the identification of the property and data such as the address, area in hectares, available infrastructure, and state registration information. It is through the property that the agribusinesses are connected.

- **GroupProperty:** This entity, the connections between the farmer and the rural farm are made, and a farm may belong to one or more farmers just as farmers may be connected to one or more rural properties.

- **Agribusiness:** This entity has the purpose of the creation and the type of animal production developed, which are defined, and tied by animal species. This entity contains information on the purpose and regulation of the activity developed in the area of the property. An agribusiness belongs to a rural property.

- **Species:** This entity contains the data of animal species registered in the state along with characteristics for livestock production, such as name, breed, MAPA code, and traceability indicator.

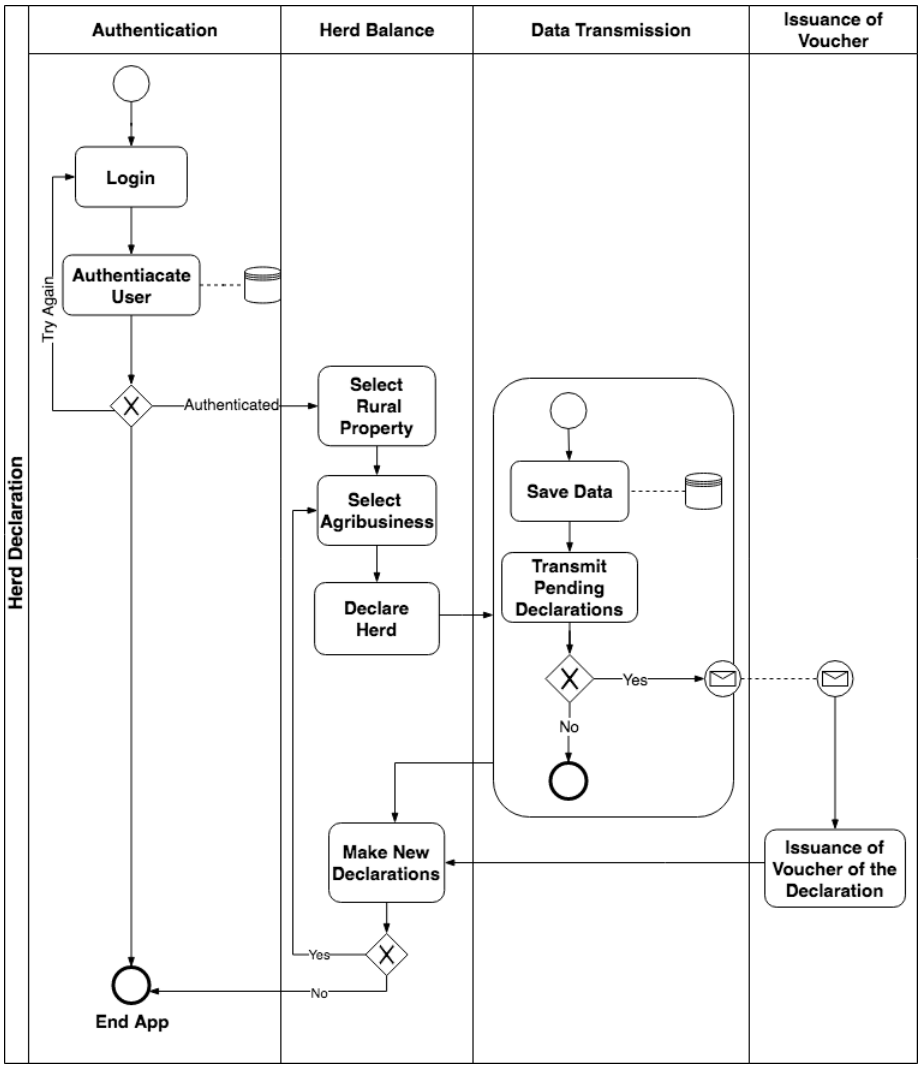

Figure 1: Overview of the proposed process.

- **HerdDeclaration:** Main entity for the periodic regulation of herd per animal species. This entity contains the declaratory herd data, such as the number of animals contained in the agribusiness, the herd category entered, and the purpose of breeding.

- **Receipt:** Entity that contains the receipt in a file format generated in the process of synchronization of the application with the external system, being assigned to the farmer with the data of the herd declaration.

4.3. Proposed Architecture

Figure 3 presents the application's architecture composed of layers that, in turn, are formed by modules. Recent studies conducted by Cadaviz *et al.*(2018) [17] and Oliveira *et al.* (2018) [18] emphasize the need for robust architectures for the development of information systems. In this sense, the architecture is segmented into the layers of presentation, business rule, data persistence, synchronizer, and crosscutting concerns. The behaviors and features of each layer are described below:

- **Presentation:** The layer (Figure 3(1)) is responsible for receiving the interactions and displaying the application screens. It is composed of two modules: interface and interface logic. The interface module represents the user interaction through the application screens, managing the *inputs* and *outputs*. The interface logic module performs the screen validations and the management of the information shown to the user, as integrated with the business rule layer.

- **Business Logic:** This layer (Figure 3(2)) centralizes the system's core logic, manages the application's behavior, and provides the structured connection between the presentation layer and data persistence. The *workflow* module orchestrates the operation of the application through compliance with the inserted business rules. The components module performs the grouping of areas (agribusiness, rural properties, among others) performing

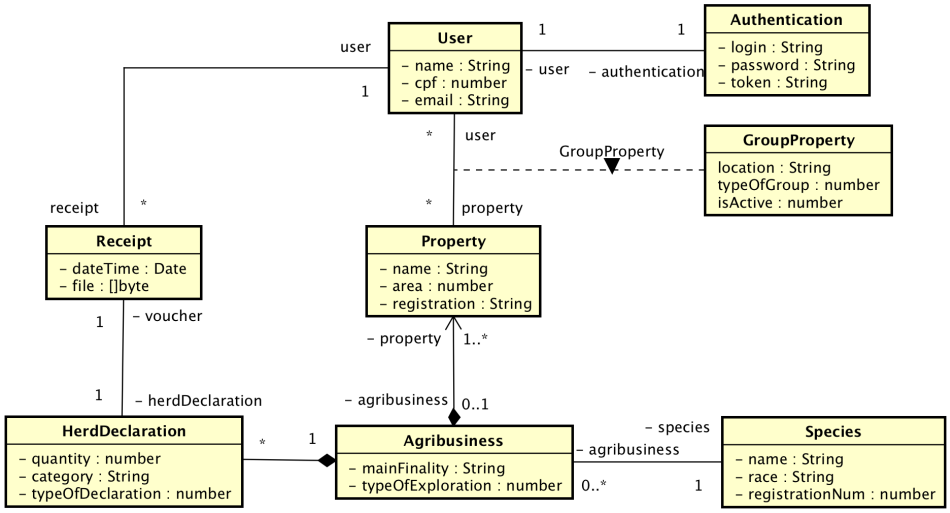

Figure 2: Conceptual model of the proposed approach.

a functional detachment, and organizing the architecture. The entities module contains the data structure by relational system entities.

- **Persistence of Data:** This layer (Figure 3(3)) is responsible for storing and querying the data contained in the application. The service worker module is responsible for managing and retrieving information when there is no internet connectivity. The database module is where the application data is stored. The memory module represents the cache memory used to make the application faster. The authentication module corresponds to user authorization and session creation.

- **Synchronizer:** This layer (Figure 3(4)), synchronizes the information, providing the data update with the external system. Through interaction with the data persistence layer, it receives the data to be transmitted and transfers the requested information. Through the use of the REST *web service*, it communicates with the external system, performing the data transition.

- **Transversional interests:** This layer (Figure 3(5)) contains the global modules of the application, being accessible by the other layers of the system. The settings module contains general information about the application. The framework module represents the components available by the *frameworks* used for application development. The file module contains the layout of the declaration receipt, in addition, it contains images, icons, and used styles, among others.

4.4. Developed Application

The proposed approach was evaluated through the development of a functional application, which allowed us to evaluate in practice the benefits of the proposed study.

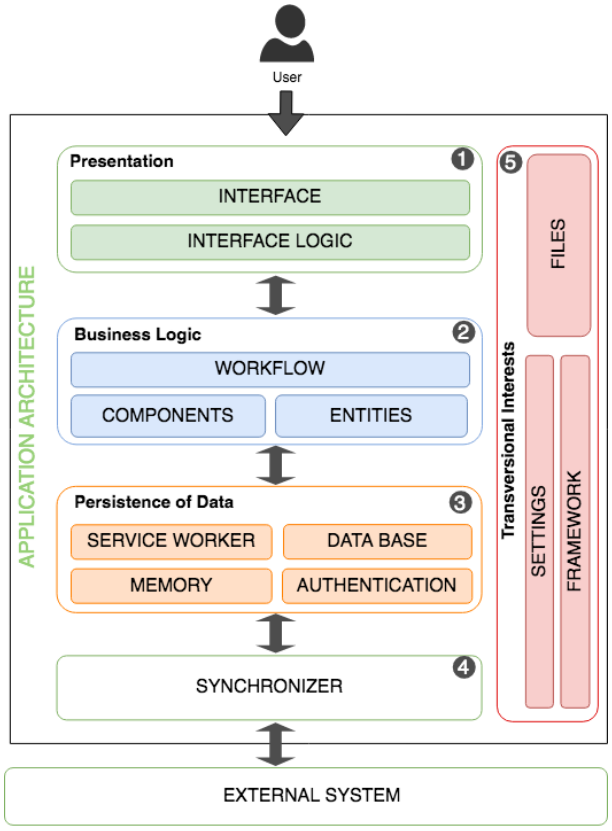

Figure 3: The proposed application architecture

Prototype interface developed. Figure 4(A) represents the application screen, containing the agribusiness registration information. It is possible to visualize the herd declarations already made along with information about the type of exploitation, the date of submission, and the status. Each block of the list is enabled for selection, allowing the user to consult each declaration in more detail. Through the button with the sum symbol, the user can make new declarations.

Figure 4(B) shows the herd declaration screen, where it is possible to select the purpose of breeding and the type of exploitation for the declaration created. On the screen, you can view the quantities that form the herd separated by categories. Finally, you can save the information locally and then send the data to the external system, finalizing the herd declaration. Figure 4(C) shows the annual herd declaration proof generated by the application when the declaration is successfully sent to the external system. The proof shows all the data entered in the user's herd declaration. It also contains a code automatically generated as a form of verification, used for validation in the veterinary inspectorates. The application enables the download of the file in PDF format.

Prototype code snippet. Figure 5 presents a snippet of code developed, referring to the main functionality of the application, which is the issuance of the herd declaration, belonging to the controller class that manages the *workflow* of the system. Initially, the method receives, as a parameter, an object of the Data Transfer Object (DTO) type, which consists of a design pattern used to transport data between different components of a system. Next, the system asks the connection service to check if there is an internet connection. If there is an internet connection, the file is sent to be processed by the receiving system, and then stored in the database, through the HTTP Post method (provided by Angular's *httpClient* framework. Finally, the system then stores the herd declaration in the browser's database, passing as a parameter, the DTO converted into JSON, the name of the base where it should be recorded and if the declaration has already been transmitted.

Prototype code snippet. Figure 5 presents an excerpt of the code developed, referring to the functionality of emitting the herd declaration, belonging to the controller class that manages the system's *workflow*, located in the business rule layer. Initially, the method receives, as a parameter, an object of Data Transfer Object type (DTO), which is a standard used to transport data between different components of a system. Next, the system requests the connection service to check if there is internet connectivity. If there is an internet connection, the file is sent to be processed by the receiving system, through the HTTP Post method (provided by the *httpClient* of the Angular's framework), and then stored in the database. Finally, the system stores the herd declaration in the local database, passing as a parameter the DTO converted to JSON, the name of the base where it will be saved, and if the declaration has already been transmitted.

4.5. Technologies Used

To make the application available on different platforms, the chosen methodology was the Progressive Web Application (PWA), which makes it possible to be accessible by web browsers. When accessed via mobile phone or *tablet*, the application has the appearance of a native application, improving the user experience. To assist in the construction of the application using the PWA methodology, the *Ionic Framework*[3] was used, which is a tool largely used in the current day industry, containing various features that aim to maximize productivity and collaborate in the maintenance of the developed application.

For the construction of visual and user interaction components, the *Angular Framework*[4] was used, as it is a tool with full integration with the *Ionic Framework* containing diverse functionalities that aim to maximize productivity and collaborate with the construction of visual and user interaction components. To store the application data, it was necessary to create a local database, for this proposal the *IndexedDB* was used, which is an API developed and maintained by the W3C, where the information is stored in the user's browser. The architecture chosen to transmit the data between the herd declaration application and the external system was REST API, for being a consolidated architecture with strong interoperability.

5. Evaluation

This section presents the development of the herd declaration evaluation. Section 5.1 introduces the process proposed to evaluate the DeclaraRS approach. Section 5.2 describes the participant selection process. Section 5.3 explains the questionnaire elaborated to evaluate the approach. Section 5.4 analyzes the quantitative and qualitative data obtained from the applied questionnaire. Section 5.5 draws up upcoming challenges that are worth investigating. Section 5.6 discusses some implications of the obtained results.

5.1. Evaluation Process

Figure 6 introduces the evaluation process, which is composed of a set of activities organized in three phases. This process is based on previously validated empirical studies [13, 19, 20]. The evaluation process is explained as follows:

- **Phase 1: Selection of participants.** In this phase, the application evaluation process begins by defining the participant profiles (input data). Regardless of technological knowledge, the selected participant must have, as a prerequisite interaction with the current declaratory herd model. Finally, obtaining the list of participants (output data) that will evaluate the next phase.
- **Phase 2: Run application.** In this phase, the application is made available to the participants (input data), through the use of a mobile device or another device with a web interface. Without any prior training, the participants interact with the application, performing the entire declaratory procedure, until obtaining the voucher. Generating any detection of inconsistencies in rules and/or errors in the application (output data).
- **Phase 3: Questionnaire application.** In this phase, the participant is directed to answer a list of questions

[3] https://ionicframework.com/

[4] https://angular.io/

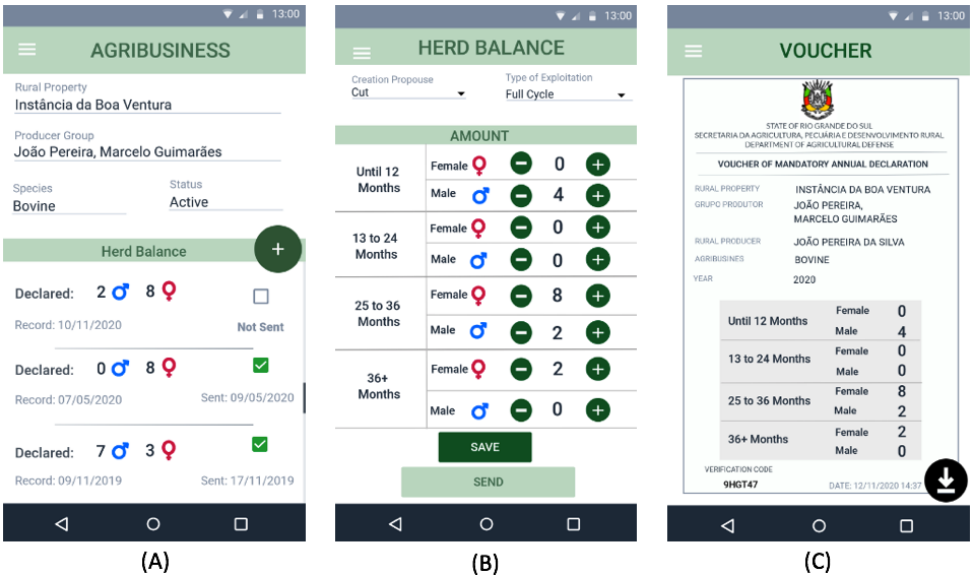

Figure 4: Interface of the developed application.

```
sendDeclaration(declarationDTO: DeclarationDTO) {

  this.connectionService.verifyConnection();
  if (this.isConnection) {
    this.httpClient.post(`${environment.urlServer}
    /declaracoes/declaraoRebanho.json`,
      {...declarationDTO, id: null})
  }
  this.LocalBaseService.store(
    JSON.stringify(declarationDTO)
    ,"declaracaoRebanho");
}
```

Figure 5: Code snippet of the feature *emit herd declaration*.

(input data) using the methodology of applying the TAM questionnaire [21], referring to the experience of usability, behavior, and importance of the tool. The collection of quantitative data (output data) is carried out after the questionnaire is completed, obtaining information to be worked on in the next phase.

- **Phase 4: Interviews and data analysis.** In this phase, the metrics obtained in the application phase of the TAM questionnaire are analyzed. With the perception already formatted, the interview process begins, to obtain qualitative data (input data). The interviews are conducted with one participant from each profile, extracting the opinions and vision they had when executing DeclaraRS. The process of analyzing the qualitative and quantitative data obtained (input data) begins through the application of metrics through the context of the responses and thus generating final results. The results obtained are generated (output data) through the characteristics and categorizations of the questionnaires applied, finally showing the degree of satisfaction of the implemented application.

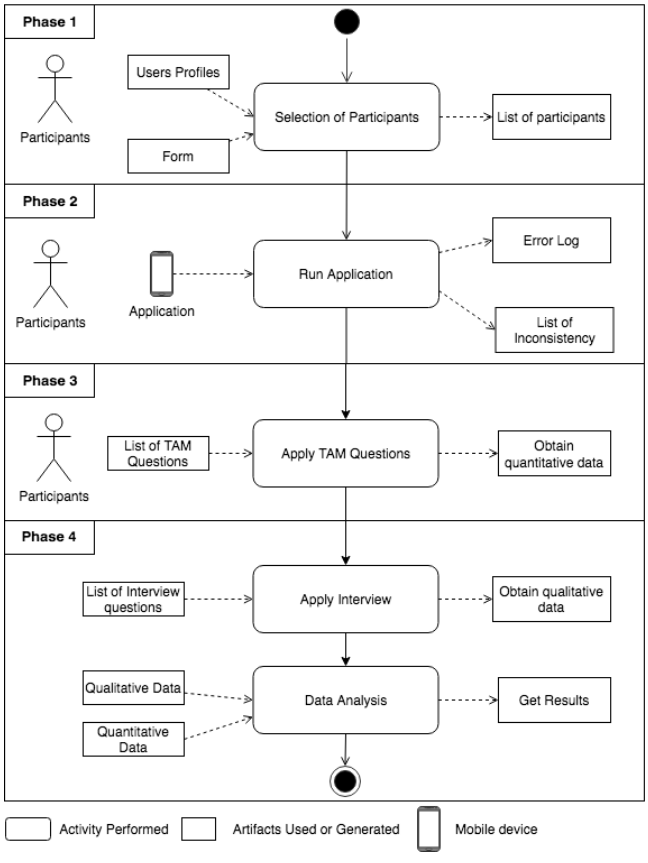

Figure 6: Evaluation process.

5.2. *Selection of Participants*

This section works on gathering information to determine the selection of participants to evaluate the application. As a prerequisite, all participants must have already interacted directly or indirectly with livestock activities. Thus, they were

categorized into three types of selected profiles as described in detail as follows:

- **Farmer:** This profile represents the system's end user. They are individuals or companies that have livestock farming activities, regardless of the size of the production. To obtain more accurate results, we searched for rural producers with distinct agricultural and livestock activities.
- **Veterinary Inspector Technician:** This profile represents the employees of the Secretary of Agriculture in the regional veterinary inspectorates in the state of Rio Grande do Sul. These professionals, among other responsibilities, are in charge of receiving the completed herd declaration form from the farmer and then registering the herd declaration, transferring the data manually into the agricultural defense system (SDA).
- **Managers:** This profile represents employees of the Secretary of Agriculture with management functions applied to the livestock sector, working directly and indirectly with herd declaration, defining processes, and obtaining the results throughout the declaration period, corresponding to the work process, along with the results obtained, according to effective state and federal laws.

5.3. Questionnaire

To evaluate the application, two questionnaires were prepared with distinct characteristics and purposes. The first aimed at identifying the participants' profiles, and relating them to the general knowledge applicable to the software. The second questionnaire focused on evaluating the proposed application in a qualitative context. The two questionnaires are described as follows:

- **Questionnaire 1: Profile of participants.** Categorized into three distinct profiles discussed in Section 5.2, the questionnaire was designed to identify fundamental characteristics for obtaining results based on the individual knowledge of each participant. It is of fundamental importance for the evaluation to identify data with general characteristics, thus building dynamic knowledge in an evaluative profile. For this, information was collected, such as age, if the participants use another similar application, if the participants have already made any herd declaration, and education level, among others.
- **Questionnaire 2: TAM questionnaire.** The preparation of this questionnaire aims to qualitatively validate the application through the Technology Acceptance Model (TAM) [21]. The topics covered for the execution of this questionnaire are the following: to validate the tool's usability by measuring the ease of interaction and learning, the application's usefulness to what is proposed, if the software's behavior corresponds, and finally if the application meets the expectations generated. To obtain the opinion survey of the questions used, the Likert scale methodology was used, where the user classifies the assessment with the following items: "Totally agree," "Partially agree", "Neutral", "Partially disagree" and "Totally disagree."

5.4. Results Analysis

Participant Profile. Table 2 presents the results obtained through the participant profile survey, identifying characteristics and opinions. The data were collected in the period from April 5 to May 10, 2021, accounting for a total of 30 participants. The profile that most contributed to the evaluation process was that of the veterinary inspection technician, with more than half of the participants (60%). In all, 10 farmers contributed to the survey, which represents 33.3% of the total number of participants. The managers correspond to 6.7%. Considering the age, the average was between 30 and 39 years, corresponding to 60% of the total participants.

Regarding education, only two participants have not completed high school, and the vast majority (70%) have a college degree. All participants use or have used other applications for mobile devices. When asked about their familiarity with the technology, all of them affirmed to have medium or high familiarity. This aspect was measured through a familiarity level ranging from 0 to 5. All participants responded with a level equal to or above 3, demonstrating that mobile technology is already a common reality in the agricultural area.

TAM questionnaire results: Table 3 presents the results obtained through the application of the technology acceptance questionnaire. The questionnaire collected data regarding the perception of ease of use, perception of the application's usefulness, and the intention to behave. The application of the TAM questionnaire to 30 participants obtained as a general result an approval of 84% and only 7.6% of disapproval. In the category of perception of use, 75.8% of the participants agreed that the application is easy to use, obtaining the same percentage when asked if the DeclaraRS is easy to learn. In this category, 15 participants answered that they fully agree (51.7%) and 7 partially agree (24.1%).

Regarding the perception of usefulness, the application proved to be satisfactory in all aspects, facilitating the declaratory work performed. DeclaraRS reduces the costs of annual herd declarations for all the profiles involved in this activity. Therefore, it contributes to reducing the time spent by the farmers traveling to the veterinarian inspectorate to declare their herds. Some questions achieved 90% approval, i.e., 27 participants agreed with the usefulness of the proposed approach. The collected answers from 24 participants suggest that the proposed approach worked properly, fulfilling its software requirements for the annual herd declaration.

Interview Results: To give consistency to the results, individual interviews were conducted with one participant of each selected profile. The objective of the interview is based on the acquisition of qualitative data concerning the perception of such participants. The objective is to contrast or reaffirm the results obtained from the application of the TAM questionnaire.

Table 2: Result of the participants profile

Features and Opinions (n = 30)	Answers	#	%
Which profile do you fit?	Farmer	10	33,3%
	Veterinary Inspector Technician	18	60%
	Manager	2	6,7%
Age	Less than 20 years	0	0%
	20 to 29 years	2	6,7%
	30 to 39 years	18	60%
	40 to 50 years	5	16,7%
	Over 50 years	5	16,7%
Education	Complete Elementary School	1	3,3%
	Incomplete High School	1	3,3%
	Complete High School	7	23,3%
	Incomplete College Degree	0	0,0%
	College Degree	21	70%
Uses other mobile apps?	No	0	0%
	Yes	30	100%
Familiarity with technology	Low Knowledge		
	0	0	0,0%
	1	0	0,0%
	2	0	0,0%
	3	9	30,0%
	4	11	36,7%
	5	10	33,3%
	High Knowledge		

Table 3: Collected data related to TAM questionnaire

	Totally Agree	Partially Agree	Neutral	Partially Desagree	Totally Desagree
Perceived ease of use					
I found DeclaraRS easy to use	13	10	3	4	0
I found DeclaraRS easy to learn	15	8	2	5	0
Perceived usefulness					
DeclaraRS would facilitate the current work of Annual Herd Declaration	19	8	1	2	0
DeclaraRS avoids wasting time on non-field activities	17	8	2	1	2
DeclaraRS will reduce time and labor costs	18	9	2	0	1
Behavioural intention to use					
DeclaraRS contemplates what is necessary to make the Annual Herd Declaration	14	10	4	2	0
Would use DeclaraRS to make the Annual Herd Declaration	19	8	2	1	0

Questioned about their impressions of the application, the participants unanimously reported that they found it easy to understand and that DeclaraRS is straightforward and objective. However, they report that, because they already have previous knowledge of the declaratory activity, such learning becomes easier, which may not be the reality for many rural producers. It was pointed out that access to information in a facilitated way through technology is a significant gain for rural activities. It was argued that the rural area needs applications that enable this type of interaction, which, in addition to being informative, helps the farmers in their daily activities, a fact that DeclaraRS provides in a positive aspect.

The interviewees reported that they sense the need to modernize the livestock sector and that the processes currently in place, in physical format, are stressful and difficult for all members involved. DeclaraRS brings a new perspective of interactions between the areas, speeding up the process and avoiding rework. According to the participant's perception, the greatest benefit that the application brings to the herd declaration is the automation of the process and the saving of time spent on the activity. For the rural producer, performing the declaration without having to leave his work environment is the best alternative, besides providing the feeling of more control over his agribusiness data.

The participants sometimes felt the necessity for more information in the steps after the declaration. They questioned the method that the declaration process would take, beyond the application's limits, emphasizing that DeclaraRS contemplates the presented proposal but suggesting improvements in terms of communication between the profiles involved.

5.5. Challenges

This section approaches the main topics of discussion identified in the course of the work, these are interpreted through the analysis of the results, enabling possible points of expansion of the work. Below, the discussions are described in detail.

Declaration of herd and family agribusiness. Family agriculture (or small producer) represents a large portion of the agricultural and livestock production, holding 25% of the rural area and 80% of the total properties in the state, according to data reported by IBGE [22]. It demonstrates in this case

vital participation in the socio-economic environment. Despite representing a significant portion of rural properties, access to resources and information are some of the difficulties faced by these rural producers. Whether by the region's infrastructure or by financial investment in improvements.

A perception obtained from the results analyzed through the interview process is that the development of technologies aimed at providing access to information is one of the means that the small-scale producer has as assistance in the development of his rural activity. Affonso and Perroni (2016) [23] emphasizes that through technological means, family farming can supply their informational requirements, minimizing the disparity in comparison to large producers. Despite the day-to-day use of technology being gradually increasing in rural areas [24], it is noteworthy that there is a technological barrier and that the development of applications requires attention to be broadly accepted. Perceived that by making technology the provider of information, it becomes a means to be considered to obtain a greater acceptance of the rural producer, filling social disparities, especially the small producer.

Public management and agribusiness. The development of agriculture is increasingly linked to the use of technology [24], making the area of activity and investment a focal and emerging point for the national economy. With this relevance factor, government initiatives began to emerge focused on the development of technology aimed at the rural environment, such as the Agro 4.0 action plan [25] which, in one of the action phases, aims to invest in the expansion of the telephone network, providing reach from the internet to more rural producers.

However, it is not enough to have connectivity in the countryside if public agencies are not prepared to integrate and promote their systems with rural producers. As reported in this work, there are physical processes that need to be computerized, which is done through the expansion of technology aimed at the rural environment. This promotes integration with the rural producers, considering the necessities of the area. As analyzed in the results of the interviews, the dissemination of information is one of the decisive factors for the acceptance of the technology and the learning process.

Challenges of mobile technology in rural environments. With the increase in the use of applications in mobile devices, rural producers are becoming more and more digitally adept [24], thereby generating a need to adapt the technology offered to the rural segment, as evidenced by the evaluation process regarding familiarity with technology and the use of applications in mobile devices.

However, the use of mobile devices in rural areas faces some barriers, especially regarding infrastructure due to the geographic location of rural properties. Connectivity is a great challenge for expanding the use of technology in rural areas, where 70% of rural properties do not have internet access [26]. One way to provide accessibility to the data network is currently through the recourse the use of the internet via satellite, which, despite having national coverage, is unfeasible due to the cost. It is expected that through the implementation of the network with 5G technology in Brazil, according to the government plan [27], a large part of the rural areas will be covered, in this way is capable of establishing a high-performance connection. These data highlight the growth in the area of application development, but with reservations due to the connection challenges faced.

5.6. Implications

The transformation through technology, replacing manual procedures, goes beyond an improvement process, becoming a necessity faced by the rural area due to cultural and business changes, as pointed out by Bischoff *et al.* (2021) [4]. This scenario can be observed through the results found in the application of DeclaraRS, where the interviewed participants emphasized the rural area's encouragement towards technology and the proposed application delivers this differential element.

DeclaraRS provides the decentralization of the herd declaration process, performed exclusively in the veterinary inspection post, affecting the entire process chain of the activity. As analyzed in the interviews and from the data of perception of use, it is demonstrated that this new workflow allows the technician, who performs the service to the producer, greater flexibility in the demands, contributing to the reduction of assistance to the rural producer at the time of the herd declaration and even preventing rework. For public managers, an increase in the volume of data and greater reliability are expected, providing a scenario closer to reality. The application gives the rural producer autonomy in the declaration process, resulting in convenience and agility

The change in the generations that have been working in the rural area contributes to technological progress in the agricultural environment. As noted by Chuang *et al.* (2020) [28], farmers from the Y generation have higher technological acceptability than past generations. The change in the age group in the rural environment, not only in the rural producer but also in professionals working in the government, can be noticed by the majority of the participants being between 30 and 39 years old. It contributes to the acceptability of the fact that DeclaraRS is developed in a technology with which the participants already have familiarity.

According to Affonso and Perroni (2016) [23], the scarcity of information in rural areas is a reality that can be overcome through the application of technology as a facilitator, besides providing benefits in the optimization of the activities. The availability of information, time and resource savings time and resource savings are examples of implications of our study. The TAM questionnaire results and interviews bring evidence in this sense.

6. Conclusions and Future Work

With Agriculture 4.0, agribusiness has gained increasing attention, aiming to strengthen and optimize its processes, as well as guarantee food security and the generation of employment opportunities. In this context, the public sector has demonstrated the need for process automation to improve the services offered to the population. The herd declaration

would be one of those processes that needed improvement. This work, therefore, presented a multiplatform approach for the declaration of herds by farmers, named DeclaraRS. Although it targets farmers, the approach also benefits the work done in the state's veterinary inspectorates and livestock management. The farmers no longer have to go to a veterinary inspectorate to submit the herd declaration; on the other hand, the inspectorates have their work facilitated with the reduction of the high flow of producers that the activity required. Managers, however, can obtain updated and more precise information, allowing them to make well-founded strategic decisions.

The proposed approach was evaluated through the development of a functional prototype, the application of the TAM questionnaire, and interviews with rural producers, veterinary inspector technicians, and public managers. The results were encouraging and show the potential for using DeclaraRS to support herd declaration in the context of rural properties. Finally, we do not claim the generalization of the results obtained; rather, our findings are associated with the context in which the study was performed. This article can be seen as a starting point for the elaboration of a more ambitious research agenda in Agriculture 4.0.

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