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APPLICATION FOR WATER QUALITY ANALYSIS FOR TILAPIA FISH FARMING IN CAGES

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ABSTRACT

With the ability to ensure food and a source of income for the planet, fish farming and fishing, which are already widely practiced activities around the world, continue to grow all over the globe. The quality of the water for this type of activity is essential. The control of chemical and physical factors of the water can guarantee the success or not of the breeding. There are many ways to analyze water quality, however, not all of them are simple or easy to manage. The growing use of mobile devices has been seeking to facilitate this task, collaborating more and more with these and other activities. In order to corroborate this evolution, the "Water Quality Monitor" application was modeled and developed, with the objective of providing, in a simple, easy and accessible way, relevant information on water quality scenarios for raising Nile tilapia fish, in cage rearing. The application development methodology was based on the Rational Unified Process, focused on objects within the programming and structured by UML diagrams. The final modeling proved to be able to support the construction of an application to meet the expected requirements for the evaluation of water quality, which during its use, allowed the control of chemical and physical factors of the water, ensuring the success of the creation, or indicating mitigating solutions for the necessary corrections to the process, being later validated in a case study.

Keywords: Decision Support. Quality Assurance. Production Process Improvement. Breeding Control. Improved Competitiveness.

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INTRODUCTION

Fish farming and fishing are strategic activities, which, according to the Food and Agriculture Organization of the United Nations (FAO, a UN agency), can ensure healthy food on the planet. With the capacity to provide quality food and income generation (FAO, 2024).

Tilapia is one of the most captive-bred freshwater species in the world, and is considered the most important, with emphasis on Nile tilapia, which is produced in more than 100 countries, with an annual commercial production of more than 1,300,000 tons (EMATER-DF, 2009; SENAR COLLECTION 208, 2018).

For success in raising any species of fish and in any system, it is essential to attend to physical and chemical factors of the water (quality). It is said that raising fish, first of all, is "creating water" (CODEVASF, 2019).

According to Almeida (2012), one of the many ways to describe water quality is by listing, individually, all the substances contained in a sample. Such a relationship can generate common parameters, such as covering varied parameters, making it difficult to understand. One of the ways is the analysis of water quality indices that can be automated through the construction of an expert system.

Expert systems are usually associated with artificial intelligence (AI). They are developed with rules that reproduce the knowledge of an expert (or specialist) and used to solve specific problems (NILSON, 1982).

For expert-type systems, the knowledge base is not just a simple collection of information (data with data). It is a basis of rules and facts, which correspond to the knowledge of specialists, with the mastery of the subject (NILSON, 1982).

According to Mendes (1997), because it is a system endowed with intelligence and knowledge, the benefits of expert systems are several:

- Extend decision-making facilities to many people;
- Improve the productivity and performance of its users;
- Reduction of the degree of dependence that organizations maintain when they find themselves in critical situations;
- Tools suitable for use in training groups of people.

There are many factors that contribute to mobile devices (*tablets, notebooks, smartphones*, etc.) being increasingly used. The reduction in the cost of these types of equipment due to the gain in scale and new technologies, making them popular and accessible to all social classes is just one of them. In addition, the need for mobility and connectivity necessary today are met by them (NETO, 2010).

Among the most important, the smartphone stands out, which has become so popular that it is no longer a luxury item to be characterized as a basic necessity of life for a large part of the population. In a survey conducted by the Brazilian Institute of Geography and Statistics (IBGE), it was found that 80.4% of the Brazilian families interviewed use smartphones as the main means of accessing the *internet*, surpassing the use of computers, *tablets*, etc. (FONSECA and ALENCAR, 2016).

The development of mobile applications has facilitated the daily lives of many people, providing portability and flexibility for a wide range of businesses: home automation, health and well-being, cloud information storage, knowledge display, etc. Such characteristics are accompanied by a growing evolution in the number of mobile application developments aimed at solving (or at least facilitating) everyday problems (PORTO, 2012).

The methodology applied for the construction of the expert system of this research was that of the *Rational Unified Process (RUP)* which, according to Emanoele (2020) and Kruchten (2000), consists of a process work structure with the objective of the product and thus based on the model of the *Unified Modeling Language (UML),* when talking about object-oriented programming. The same author points out that UML composes a language to define a sequence of artifacts and assist in the execution of the tasks of the system to be developed, through different types of diagrams and that even though RUP is used for complex projects and with extensive teams, it allows activities and artifacts to be carried out according to the team's choice, can be adapted to make the process more agile.

Thus, considering the above approaches, the development presented in this research is the modeling, construction and testing in a case study, of a specialist application for mobile devices, capable of receiving data on the main environmental variables that reflect on the quality of water for Tilapia fish farming, which allows the control of chemical and physical factors of the water, thus being able to guarantee the success of the creation, or indicating mitigating solutions for the necessary corrections to the process.

METHODOLOGY

MODELING

This section shows how the expert application "*Water Quality Monitor*" was modeled and developed.

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For the static and behavioral structuring of the application, the Unified Modeling Language (UML) diagrams were used, whose specification can be found in (UML, 2024), "Class Diagram", "Case and Use Diagram" and "Sequence Diagram". According to Rumbaugh (2004), UML is a visual modeling language, used to specify, visualize, build and document systems.

SYSTEM ARCHITECTURE

Classes are digital representations of real-world objects, they have attributes, behaviors, and relationships. The sample of a water analysis and its parameters are an example of a class and were created from a UML class diagram, which represents all the attributes and methods necessary to carry out the system analyses (UML, 2024).

UML's "case and use diagram" and its descriptions complement the modeling. They represent the behavior of the system and the responsibilities of its component actors.

DATABASE

Classes are digital representations of real-world objects, they have attributes, behaviors, and relationships. The sample of a water analysis and its parameters are an example of a class and were created from a UML class diagram, which represents all the attributes and methods necessary to carry out the system analyses (UML, 2024).

For the "*Water Quality Monitor*" application, the database was created following the structure of the "Analysis" class described above, in the System's architecture and according to indications from Silberschatz, Korth and Sudarshan (2010).

SYSTEM PROCESSES

The processes necessary for the operation of the System were modeled using UML sequence diagrams (UML, 2024).

LANGUAGE AND DEVELOPMENT PLATFORM

For the application coding process, the installation of the development environment (IDE), *Android Studio*, version *Chipmunk* // 2021.2.1 (official GOOGLE tool), as well as the configuration of the *Dart language* (DEVMEDIA, 2023), and the *Flutter framework* (IOPSCIENCE, 2020) were carried out.

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The expert application was developed entirely in the *Dart programming language* in conjunction with the *Flutter framework* and some of its component packages and tools (dependencies):

- *SQFLite:* database present in the programming language itself, with compatibility with mobile devices);
- *INTL: "*slider*" type components*, selection bar for entering values;
- *CHARTS:* "graph" type components, for displaying information.

GRAPHICAL FEATURES AND INTERFACES

The system's functionalities for performing the analyses were inserted in a set of graphical *interfaces* for smartphone screens that allow users to perform analyses with the possibility of storing, editing or creating new analyses with changes in the parameters of the system's input variables. The system was also modeled in order to issue mitigating recommendations for a better performance of the breeder, given the scenario presented for analysis.

CASE STUDY

To carry out the tests in the specialist application "*Water Quality Monitor*", a new analysis was added and the values for the environment variables (temperature, dissolved oxygen, pH, ammonia, and transparency) were inserted, respecting the limit values raised in the systematic review of the literature, in Mastelini and Mollo Neto (2022), and which will receive the rules formulated in the MatLab tool of the algorithm developed and embedded in the construction of this application research.

RESULTS

System Modeling:

During the project, it was observed the need to create only one class to meet the functionalities of the specialist system "*Water Quality Monitor*", represented in FIGURE 1.

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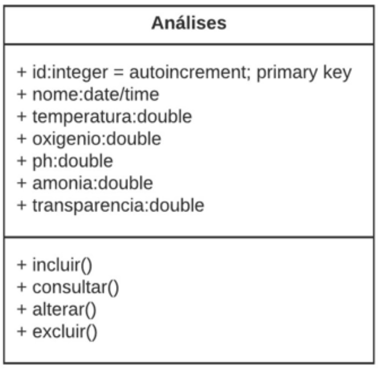
Figure 1: Class diagram ("Analyses" table).



Source: Constructed by the authors.

As shown in FIGURE 1, the "Analytics" table will contain all the necessary attributes of the expert application, namely:

• ID: Attribute of the numeric type. Auto-incrementing and classified as the table's primary key (never repeats);

• Name: attribute of type date. Designed so that each analysis, in addition to its ID (which is hidden), has unique information visible, for user control, so each analysis will have the full date (dd/mm/yyyy) saved in its name plus the time 00:00;

• Temperature: Numeric type attribute. Field that will receive the value of the water temperature variable, which can be an integer or real value;

• Oxygen: numerical attribute. Field that will receive the value of the variable dissolved oxygen of the water, which can be an integer or real value;

• pH: Attribute of the numeric type. Field that will receive the value of the pH variable of the water, which can be an integer or real value;

• Ammonia: numeric type attribute. Field that will receive the value of the variable ammonia of the water, which can be an integer or real value;

• Transparency: Numeric attribute. Field that will receive the value of the water transparency variable, which can be an integer or actual value.

The "Analyses" table also contains, in itself, the methods:

• Include: it will be possible to add as many analyses as you wish;

• Consult: it will be possible to consult, at any time, analyses already carried out;

• Change: it will be possible to change the values of the environment variables;

• Delete: it will be possible to delete analyses that have already been recorded.

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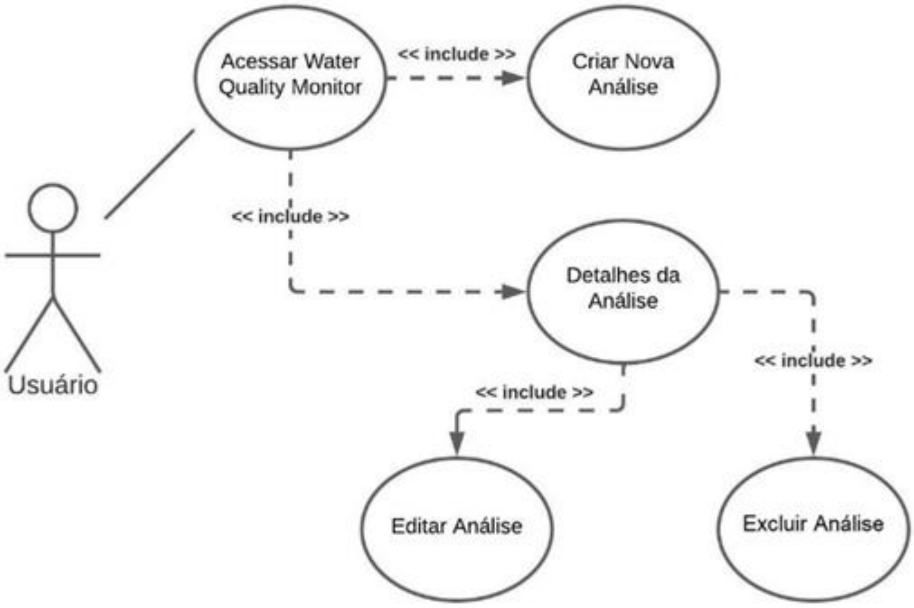
The "case and use diagram" in FIGURE 2 presents the procedures contained in the "Analysis" class modeled in FIGURE 1 and are the same ones available in the application as functionalities.

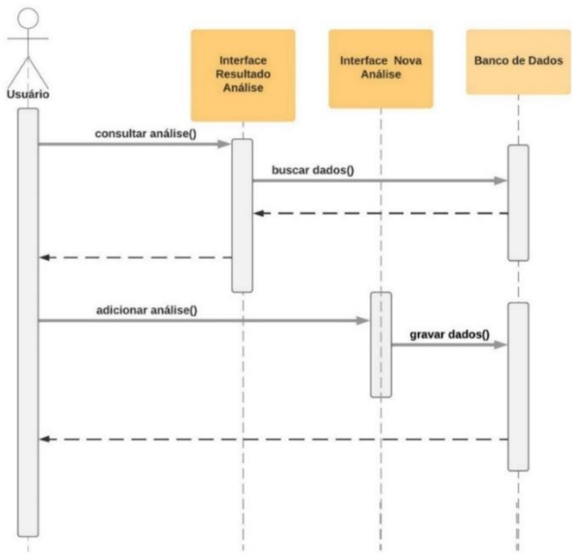
Figure 2: Case and use diagram – "*Water Quality Monitor*" application.



Source: Constructed by the authors.

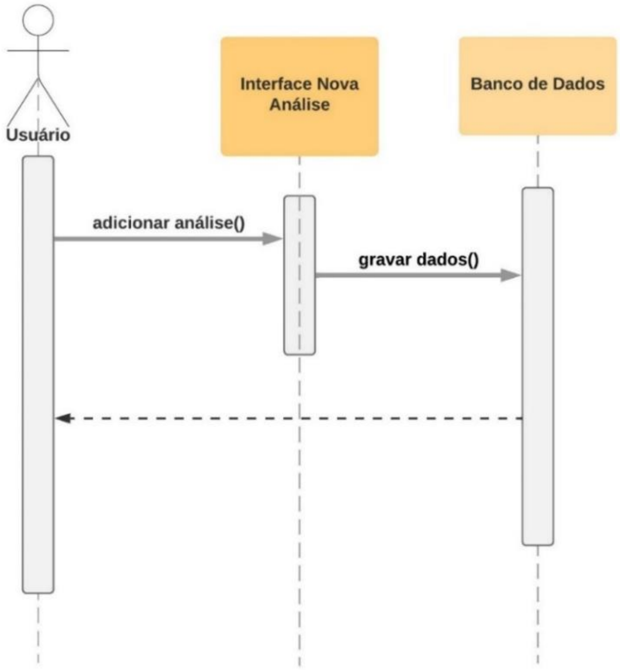
The "sequence diagrams" demonstrate the requests and responses that each interface of the application has, facilitating the understanding of the processes contained in it, as shown in FIGURES 3, 4 and 5.

Figure 3: Sequence diagram – repository interface.



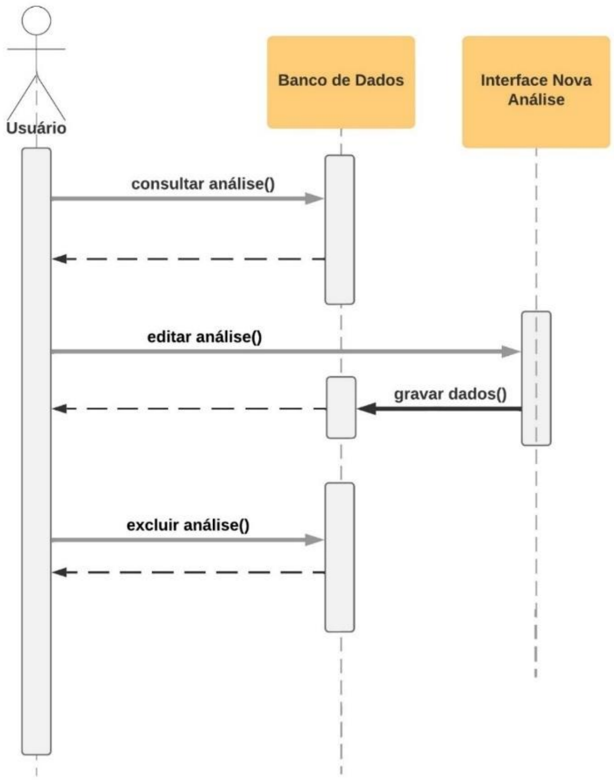
Source: Constructed by the authors.

Figure 4: Sequence diagram – new analysis interface.



Source: Constructed by the authors.

Figure 5: Sequence diagram – interface result analysis.



Source: Constructed by the authors.

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Features and *graphical interfaces:*

When running the specialist application "*Water Quality Monitor*", the user will access the initial interface of the application, containing the logo and name of the application, as shown in FIGURE 6. The *initial interface* is programmed with the "*splash*" functionality, which will automatically call the next *interface* (repository) after six seconds have passed.

Figura 6: Interface inicial "Water Quality Monitor".

Source: Constructed by the authors.

The "*repository interface*" is the home of the expert application, which "calls" all the functions of the application. It is in this *interface* that it is possible to have access to analyses already performed and/or create a new analysis. Its functions are available in FIGURE 7.

The images in FIGURE 7 (a) show the repository *interface* without any registered analysis; and (b) show the repository *interface* with already registered analyses. In both it is possible to see the "+" button, for the action of adding a new analysis.

By clicking on the "+" option, the new *analysis interface* will be called. This *interface* requires the interaction of the user, who must enter the values of the ambient variables of

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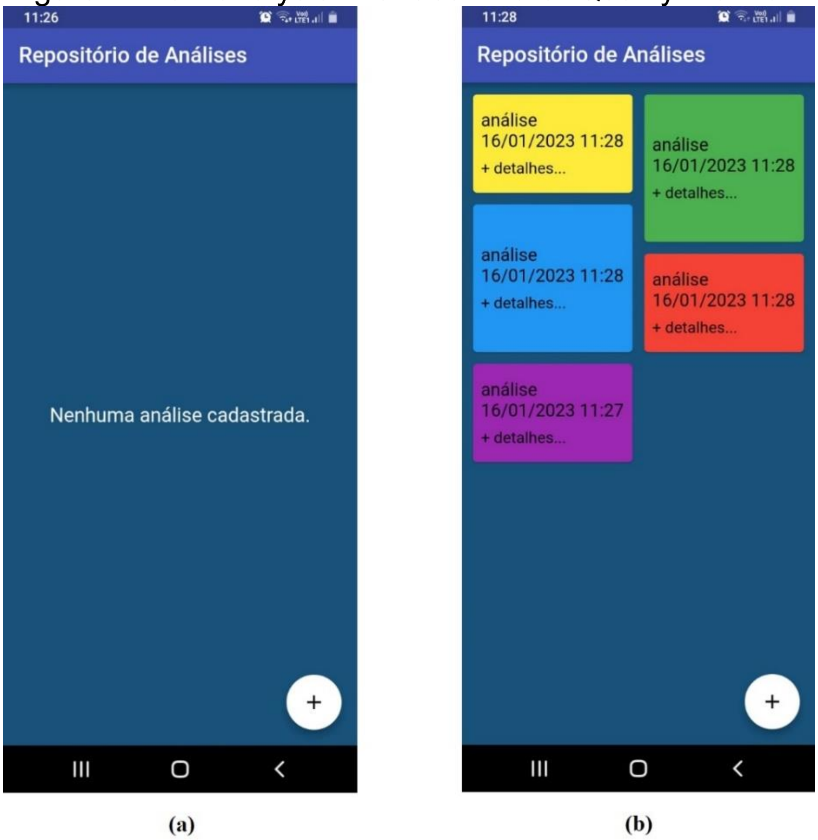
the water (collected at that moment). The entry of values is performed by "*sliders*", which are slidable bars (prevent the entry of values different from those expected). Each variable has its "*slider*", which also has the information of minimum and maximum values at its ends.

Figure 7: New analysis interface "Water Quality Monitor".



Source: Constructed by the authors.

The images in FIGURE 8 show the functionalities and options of the *new analysis interface* (a) shows the *interface* as soon as the user accesses it, in it, the values of the variables come by default, zero; (b) shows the *interface* that has already undergone user interaction, when clicking and sliding the "*sliders*" or bars, the values are highlighted in the field below the variable name; (c) shows another feature of this *interface*, when clicking (and holding) on the name of the variable, a dialog box is displayed, informing which measuring tool or instrument is used to collect data on that variable. In all images it is also possible to observe the "record" button.

By pressing this button, the application saves the data entered in the database, generating a new analysis that will be displayed in the *repository interface* (FIGURE 7). The user also has the option to return to the repository *interface* without launching a new analysis, just click on the icon with the "arrow" back.

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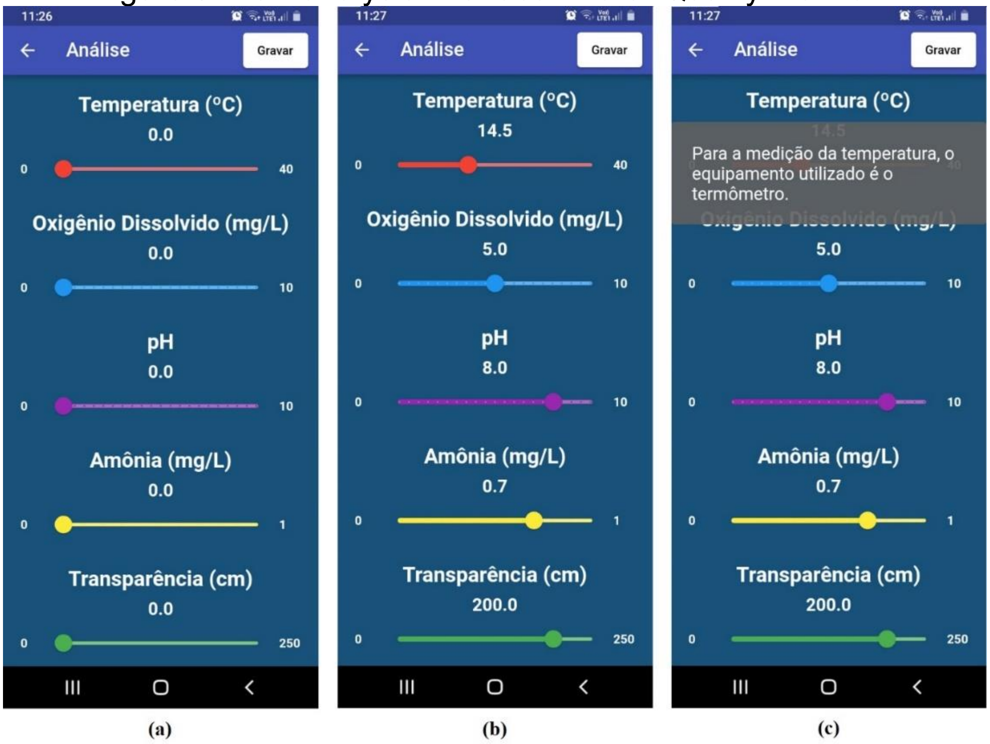
Subsequent launch of a new analysis (or if it is necessary to consult the results of an analysis already launched), the user can access it through the *repository interface* (FIGURE 7), clicking on it, so the analysis result *interface* will be "called".

Figure 8: New analysis interface "Water Quality Monitor".



Source: Constructed by the authors.

The result analysis interface is where the data entered by the user, which are saved in the application's database, are confronted with the rules obtained in the algorithm developed in the work "*Control and management of water quality for nile tilapia fish in net tanks based on fuzzy modeling*" by Mastelini *et al.* (2023), and presented to the user, also contains several functions and options. The summary of the rules built in MatLab for the algorithm can be seen in CHART 1, where it is possible to see the *analysis result interface* in FIGURE 9.

The application also provides the user with information about each variable, the *status* of each one and, in some cases, actions that can contribute to the control of that variable, along with graphs, which show the value of the variable (inserted in that analysis) and the values of its *status* (lethal, alert and ideal).

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In image (b) it is possible to notice that the application has the interactive chart function, when clicking (and holding) on the desired column (in any column and chart), it will display information about that *status* (reference), so that the user is aware of these.

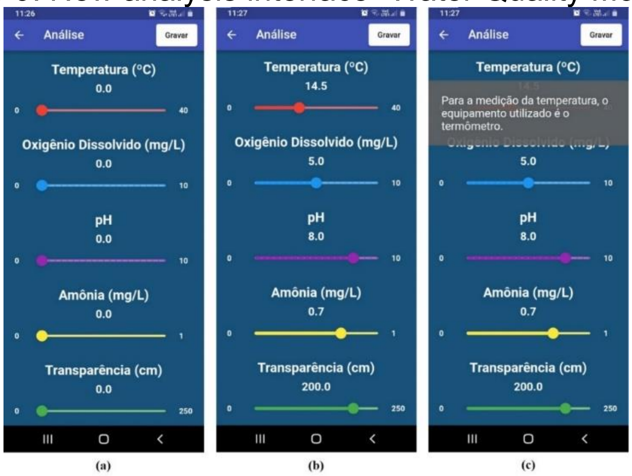
The analysis result interface also has the option to go back to the repository interface (FIGURE 7), "arrow" icon; edit analysis (new analysis interface, FIGURE 8), which will overwrite the data saved from that analysis in the database and the delete analysis option, which will permanently delete that analysis from the database.

Table 1: MatLab algorithm ruleset for water quality scenarios.

Rule	Scenario
If lethal temperature, or lethal oxygen, or lethal pH 1, or lethal ammonia.	Terrible Quality
If lethal temperature, or lethal oxygen, or lethal pH 1, or lethal ammonia.	Terrible Quality
If ideal temperature, and ideal oxygen, and ideal pH, and ideal ammonia and high transparency.	Optimal Quality
If ideal temperature, and ideal oxygen, and non-lethal pH 1, and non-lethal ammonia, and high, or medium, or low transparency.	Good quality
If ideal temperature, and ideal oxygen, and non-lethal pH 2, and non-lethal ammonia, and high, or medium, or low transparency.	Good quality
If alert temperature 1, and alert oxygen, and non-lethal pH 1, and non-lethal ammonia, and high, or medium, or low transparency.	Poor Quality
If alert temperature 1, and alert oxygen, and non-lethal pH 2, and non-lethal ammonia, and high, or medium, or low transparency.	Poor Quality
If alert temperature 2, and alert oxygen, and non-lethal pH 1, and non-lethal ammonia, and high, or medium, or low transparency.	Poor Quality
If alert temperature 2, and alert oxygen, and non-lethal pH 2, and non-lethal ammonia, and	Poor Quality

Source: Constructed by the authors.

Figure 9: New analysis interface "Water Quality Monitor".



Source: Constructed by the authors.

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The images in FIGURE 10 (a), (b), (c). (d) and (e), show the user a summary of the quality of the water scenario of that analysis (chosen in the repository interface), bringing at the beginning, the output variable (very bad; bad; good. excellent), variables resulting from the algorithm developed in the MatLab tool with Fuzzy logic, which directly reflect with the related values of the variables temperature, dissolved oxygen, pH, ammonia and transparency.

Figure 10: Interface result analysis "Water Quality Monitor".

Source: Constructed by the authors.

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The application also provides the user with information about each variable, the *status* of each one and, in some cases, actions that can contribute to the control of that variable, along with graphs, which show the value of the variable (inserted in that analysis) and the values of its *status* (lethal, alert and ideal).

In image (b) it is possible to notice that the application has the interactive chart function, when clicking (and holding) on the desired column (in any column and chart), it will display information about that *status* (reference), so that the user is aware of these. The analysis result interface also has the option to go back to *the repository interface* (FIGURE 8), "arrow" icon; edit analysis (new analysis interface, FIGURE 9), which will overwrite the data saved from that analysis in the database and the delete analysis option, which will permanently delete that analysis from the database.

The *resulting* statuses of the water quality scenarios of the "*Water Quality Monitor*" application follow TABLE 2:

Table 2: Status of water quality scenarios.

Scenarios
Terrible Quality
Poor Quality
Good quality
Optimal Quality

Source: Constructed by the authors.

Minimum Configurations:

With the completion of the development of the specialist application, it was possible to test it for its optimization, using it on different devices (between *smartphones* and *tablets*), where it was possible to prove a satisfactory use in configurations already below those currently found in the market. With this, QUADRO 3 aims to provide the minimum recommended configurations of mobile devices for the correct functioning of the "*Water Quality Monitor*" application.

Table 3: Minimum settings.

Android OS Version:	9.0 (Pie)
RAM:	1GB
Storage:	16GB
Screen Size:	4.7

Source: Constructed by the authors.

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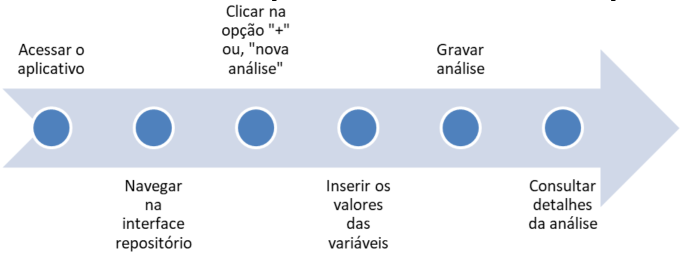
Case Study:

To test and validate the operation of the application, a test scenario, taken from a real situation of a Tilapia farm in a net tank, was inserted into the system. The sequences of processes and the values entered in this test follow the information in FIGURE 11 and TABLE 4.

Figure 11: Interface analysis result "Water Quality Monitor".



Source: Constructed by the authors.

Table 4: Variable values environment.

New Analysis	
Temperature	26
Dissolved Oxygen	5
ph	4.5
Ammonia	0.2
Transparency	158

Source: Constructed by the authors.

Application Testing:

The first step is to open the "*Water Quality Monitor*" application and wait for the repository interface to load (where all the analyses are located), then select the "+" option (new analysis), as shown in FIGURE 12.

Figure 12: Application testing – part 01.

Source: Constructed by the authors.

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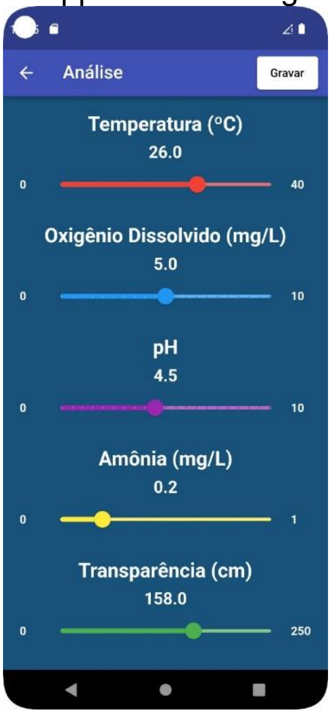
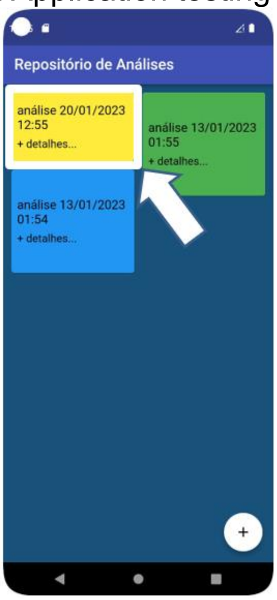
When you activate the option in FIGURE 12, the "new analysis" interface will be displayed. In this step, the values classified in TABLE 2 will be inserted. At the end of the data entry process, the "save" option must be activated, to save the analysis in the database and return (automatically to the *repository interface*), as shown in FIGURES 13 and 14.

Figure 13: Application testing – part 02.



Source: Constructed by the authors.

Figure 14: Application testing – part 03.



Source: Constructed by the authors.

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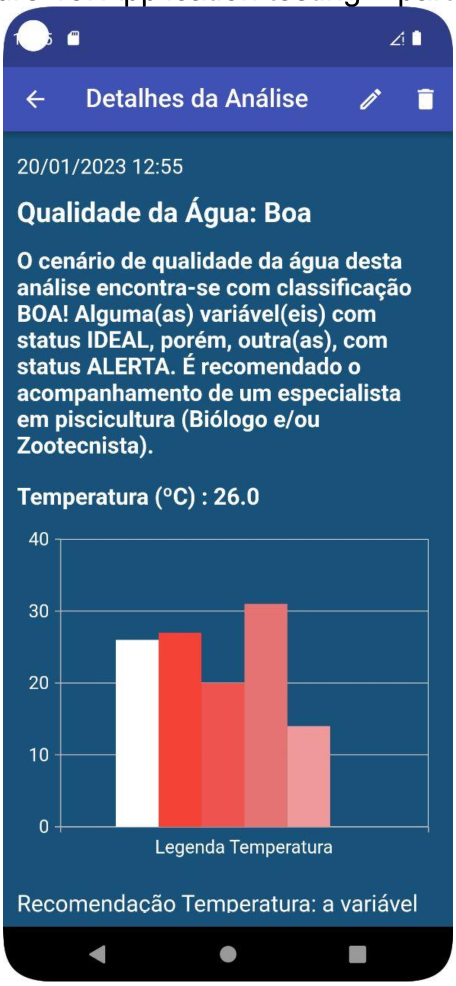
If the previous process goes well, the newly inserted analysis will be displayed in the repository interface (the list is descending, that is, the last included analysis will be displayed first), as shown in FIGURE 14.

To consult the analysis (whether the last one entered or any other saved in the application's database), just click on the desired analysis and the application will call the analysis result interface, which will bring the information regarding the water quality scenario and its variables, shown in FIGURE 15

.

Figure 15: Application testing – part 04.



Source: Constructed by the authors.

It is possible to see from FIGURE 15 that the result of the water quality scenario of the analysis created for the test was considered by the algorithm as Good.

The analysis *result interface* brings, in addition to the situation of the inserted scenario, relevant information from the context as a whole and also from the individual variables, such as the *status* that each variable is in (in that analysis), the possible *statuses*

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that each variable may have within the application (along with their reference values) and how they can be treated, if necessary. To view, just "scroll" the screen, as shown in FIGURE 16.

Figure 16: Application testing – part 05.

Source: Constructed by the authors.

DISCUSSION

Easy to use, with friendly *interfaces* and good interaction, the specialist application proved to be a functional tool, delivering relevant and quality information to its users, as presented in the works of Neto (2010), Fonseca and Alencar (2016) and Porto (2012), on analysis of water quality scenarios for fish farming and individual details of each of the variables that the application considers, without the need for robust *hardware* and/or *internet* access, and with the possibility of mobility, as discussed in the works of Mendes (1997) and Nilson (1982).

Contributing to the identification and describing the characteristics of the variables that reflect on the water quality for the breeding of Nile tilapia, not only in terms of positive values, but also as an alert, the literature review also collaborated with information and details on the basic structure and differential between the methods of rearing in cages and excavated tanks (EMATER-DF, 2009; SENAR COLLECTION 208, 2018; CODEVASF, 2019; ALMEIDA, 2012).

It was possible to apply mathematical methods, such as Fuzzy logic and Mamdani's inference system in the MatLab tool, receiving the values of the input variables and applying rules to them, which finally delivered descriptive values of output variables, enabling the reading of the water quality scenario of that analysis. Thus creating, as a result, the algorithm that was embedded in the expert application developed by Mastelini and Mollo Neto (2022) and Mastelini *et al.* (2023).

Process improvements and the inclusion of new features are expected in future research to the specialist application, incorporating new possibilities for analysis through the improvement of modeling and analysis as provided by Emanoele (2020), UML (2024) and Rumbaugh (2004).

The registration process of the "*Water Quality Monitor*" application was also carried out:

Patent: Computer Program. Registration number: BR512023000989-0, registration date: 08/29/2022, title: "*WATER QUALITY MONITOR - FISH FARMING*", Registration institution: INPI - National Institute of Industrial Property.

CONCLUSION

The specialist application "*Water Quality Monitor*", modeled and developed in this research work, proved to be functional and capable of delivering what was proposed in its main objective, with fast and quality information about the water quality scenarios with their main environment variables. Thus confirming that the use of technologies such as *software*, together with the knowledge of specialists, can corroborate an improvement in the analysis and planning processes, helping the creator, user of the solution, in decision making. In addition, it is easy to use, does not require powerful *hardware* and can be used in the field, as it is a mobile application and without the need for *an internet* connection.

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