English

SOFIA: Pioneering and Innovation in the Telessaúde Brasil Redes Program

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Date of Receipt: June 17, 2024 | Approval date: January 6, 2025

Abstract

Objective: *To describe the development of the Interactive Online Strengthening System for Primary Care platform, created by the Telehealth Center at the Federal University of Maranhão, aimed at speeding up responses to the queries of primary care health professionals using artificial intelligence.* ***Method:*** *A descriptive approach detailing the development and functionalities of the platform, following software development standards. This includes requirements analysis, data structure planning, migration of existing information, implementation of authentication, and automated updates. The search engine used Python with the Term Frequency - Inverted Document Frequency algorithm, applying text filtering and stemming techniques, connecting to the database to query all answered teleconsultations.* ***Results and discussion:*** *By reusing the nearly 29,000 responses from the center and using the algorithm, a teleconsultation workflow was created, reducing response time to less than 3 seconds, significantly lower than the 72 hours predicted by the Ministry of Health. The teleconsultation process was executed through the new flow, increasing the speed of responses.* ***Conclusion:*** *The platform exemplifies how technological innovation can solve complex challenges in public health by providing quick and accurate responses to improve the quality of care in Primary Care.*

Keywords: *Artificial Intelligence, Remote Consultation, Telemedicine.*

Resumen

SOFIA: Pioneirismo e Innovación en el Programa Telessaúde Brasil Redes

Objetivo: *Describir el desarrollo de la plataforma del Sistema Interactivo de Fortalecimiento Online para la Atención Primaria, creada por el Centro de Telesalud de la Universidad Federal de Maranhão, con el objetivo de agilizar las respuestas a las dudas de los profesionales de la salud de la Atención Primaria utilizando inteligencia artificial.* ***Método:*** *Enfoque descriptivo detallando el desarrollo y las funcionalidades de la plataforma, siguiendo estándares de desarrollo de software. Incluye análisis de requisitos, planificación de la estructura de datos, migración de información existente, implementación de autenticación y actualizaciones automatizadas. El motor de búsqueda utilizó Python con el algoritmo Term Frequency - Inverted Document Frequency, aplicando técnicas de filtrado y stemming de texto, conectándose a la base de datos para consultar todas las teleconsultas respondidas.* ***Resultados y discusión:*** *Al reutilizar las casi 29,000 respuestas del centro y utilizar el algoritmo, se creó un flujo de teleconsulta, reduciendo el tiempo de respuesta a menos de 3 segundos, significativamente inferior a las 72 horas previstas por el Ministerio de Salud. El proceso de teleconsultas se realizó a través del nuevo flujo, aumentando la rapidez de las respuestas.* ***Conclusión:*** *La plataforma ejemplifica cómo la innovación tecnológica puede resolver desafíos complejos en la salud pública proporcionando respuestas rápidas y precisas para mejorar la calidad de la atención en la Atención Primaria.*

Palabras clave: *Inteligencia Artificial, Consulta Remota, Telemedicina.*

Resumo

SOFIA: Pioneirismo e Inovação no Programa Telessaúde Brasil Redes

Objetivo: *Descrever o desenvolvimento da plataforma de Sistema Online de Fortalecimento Interativo para Atenção primária, criada pelo Núcleo de Telessaúde da Universidade Federal do Maranhão, para agilizar as respostas às dúvidas dos profissionais de saúde da Atenção Primária, utilizando inteligência artificial.* ***Método:*** *Abordagem descritiva detalhando o desenvolvimento e as funcionalidades da plataforma, seguindo padrões de desenvolvimento de software. Inclui análise de requisitos, planejamento da estrutura de dados, migração de informações existentes, implementação de autenticação e atualizações automatizadas. O motor de busca, utilizou Python com o algoritmo Term Frequency - Inverted Document Frequency, aplicando técnicas de filtro de texto e stemming, conectando à base de dados para consulta de todas as teleconsultorias respondidas.* ***Resultados e discussão:*** *Com a reutilização das quase 29 mil respostas do núcleo e o uso do algoritmo, foi criado um fluxo de teleconsultoria, reduzindo o tempo de resposta para menos de 3 segundos, muito inferior às 72 horas previstas pelo Ministério da Saúde. O processo das teleconsultorias foi realizado pelo novo fluxo, aumentando a agilidade nas respostas.* ***Conclusão:*** *A plataforma exemplifica como a inovação tecnológica pode resolver desafios complexos na saúde pública, para fornecer respostas rápidas e precisas a fim de melhorar a qualidade do atendimento na Atenção Primária.*

Palavras-chave: *Inteligência Artificial, Consulta Remota, Telemedicina.*

INTRODUCTION

A digital health ecosystem is one of the most promising solutions to overcome the healthcare access gap, especially in countries like Brazil, where inequality is a significant challenge. With the rapid advancement of technology, especially in the area of artificial intelligence, the potential of Telehealth can be expanded, allowing more people access to quality healthcare services, regardless of their geographic location or socioeconomic status[1-3].

Telehealth is one of the applications of digital health, which consists of the use of Information and Communication Technologies (ICT) to support the promotion, prevention, diagnosis, and treatment of diseases, as well as to improve health management and the education of professionals and users, through remote health services, such as teleconsulting, telemonitoring, teleeducation, telediagnosis, among others. Teleconsulting is one of the services offered by the Telehealth Brazil Networks Program (*Programa Telessaúde Brasil Redes*), whose main objective is to improve Primary Health Care (PHC) by providing technical and educational support to health professionals working in this area, especially in remote and resource-poor regions. It is an effective way for PHC health professionals to resolve doubts and improve their clinical conduct, all remotely[4-6].

In the dynamic scenario of Brazilian public health, where agility and accuracy of information are crucial for the quality of care, innovation has emerged that redefines the standards of teleconsultations: the SOFIA platform (Online System for Interactive Strengthening of Primary Care-*Sistema Online de Fortalecimento Interativo para Atenção Primária*), developed by the Telehealth Center of the Federal University of Maranhão (UFMA), its platform registered with the National Institute of Industrial Property (INPI-*Sistema Online de Fortalecimento Interativo para Atenção Primária*) under number: BR512019002091-0[7].

SOFIA was developed to meet the growimg demands of questions from Primary Health Care workers in the State of Maranhão regarding clinical procedures, health actions, and issues related to the work process, promoting the exchange of knowledge and the discussion of clinical cases in a collaborative manner, with personalized answers based on scientific evidence.

SOFIA was made with Design techniques based on User Experience (UX), which goes beyond the physical part, focusing on the sensory experience and User Interface (UI), which promotes interaction with the productin software development. It lies in its pioneering role in using artificial intelligence to speed up responses, being the first Platform of the *Telessaúde Brasil Redes* Program to adopt this technology. This innovation represents a significant advance in continuing education, making Teleconsultations more agile and efficient, and contributing to the qualification of the services provided.

In addition to the SOFIA platform, the Telehealth Center of the Federal University of Maranhão also developed the SOFIA App, democratizing access to all users of the Web platform who work in the PHC of the state of Maranhão. The application is registered with the INPI under number: BR512021000020-0[8].

OBJECTIVE

To describe the development of the SOFIA Platform: Online System for Interactive Strengthening of Primary Care developed by the Telehealth Center of the Federal University of Maranhão, with the innovation of using Artificial Intelligence.

METHODOLOGY

This is a descriptive approach to the development and functionalities of the SOFIA Platform, following software development standards.

The SOFIA platform was conceived and developed in 2018 by the Telehealth Center of the Federal University of Maranhão (UFMA).

The entire methodology for developing SOFIA will be extensively detailed, showing the progress of each stage carried out to build the system and a description of the resources and concepts implemented, enabling to understand what was developed.

It includes requirements analysis, data structure planning, migration of existing information, implementation of authentication, and automated updates. The search engine used Python with the Term Frequency - Inverted Document Frequency algorithm, applying text filter and stemming techniques, connecting to the database to consult all answered teleconsultations.

RESULTS AND DISCUSSION

The Telehealth Center of the University of Maranhão began developing the new Platform in 2018 to meet the entire flow of creation, regulation, and response of teleconsultations. The platform will initially be exclusive to the Telehealth Center of Maranhão. Still, new profiles of centers can be inserted to facilitate the

system's maintenance in case other states decide to adhere to the implemented functionalities.

The entire software engineering process in requirements analysis and data structure planning was designed and documented according to software development process standards and the architected data dictionary.

After developing the structured data model, the existing teleconsulting information was migrated from the NTS. The migration code was written to be executed regularly by a monitoring server. After defining the structure and migrating data to SOFIA, the process of developing the functionalities of the platform's main players and general functionalities continued.

Authentication

With the information from over 3,000 users migrated from the database of the monitoring platform currently in use, the authentication architecture was implemented. SOFIA attempts to bring an idea of interaction closer to the email system but with customizations and more advanced features depending on the user, providing a more interactive look.

Each type of actor in the system has its mailbox with some shared views to avoid duplicate code. When logging in, the type of user's activity is tested, and the user is redirected to the corresponding mailbox.

Timed updates

SOFIA has features that are executed from time to time (hourly, minute by minute, etc.) to perform updates and notifications regarding users, teleconsultations, and data migration. The features with these characteristics were implemented using Laravel's Task Scheduler.

Each teleconsultation goes through different statuses, from the moment it is sent by the requester to the receipt of the response and evaluation. Some statuses must be updated automatically to identify delays in the process stages: delayed waiting for teleregulation, which is when the teleregulator exceeds the established regulation time; delayed waiting for teleconsultant, which is when the specialist professional exceeds the established time to accept responding to the teleconsultation; delayed response in execution, which is when the entire process exceeds the 72 hours established for the response to reach the requester; and, finally, expired teleconsultation, which is when the requester receives the response but exceeds 30 days to perform the reading. The SOFIA system checks every hour whether the pre-established deadline has been exceeded and, thus, automatically updates the teleconsultation status.

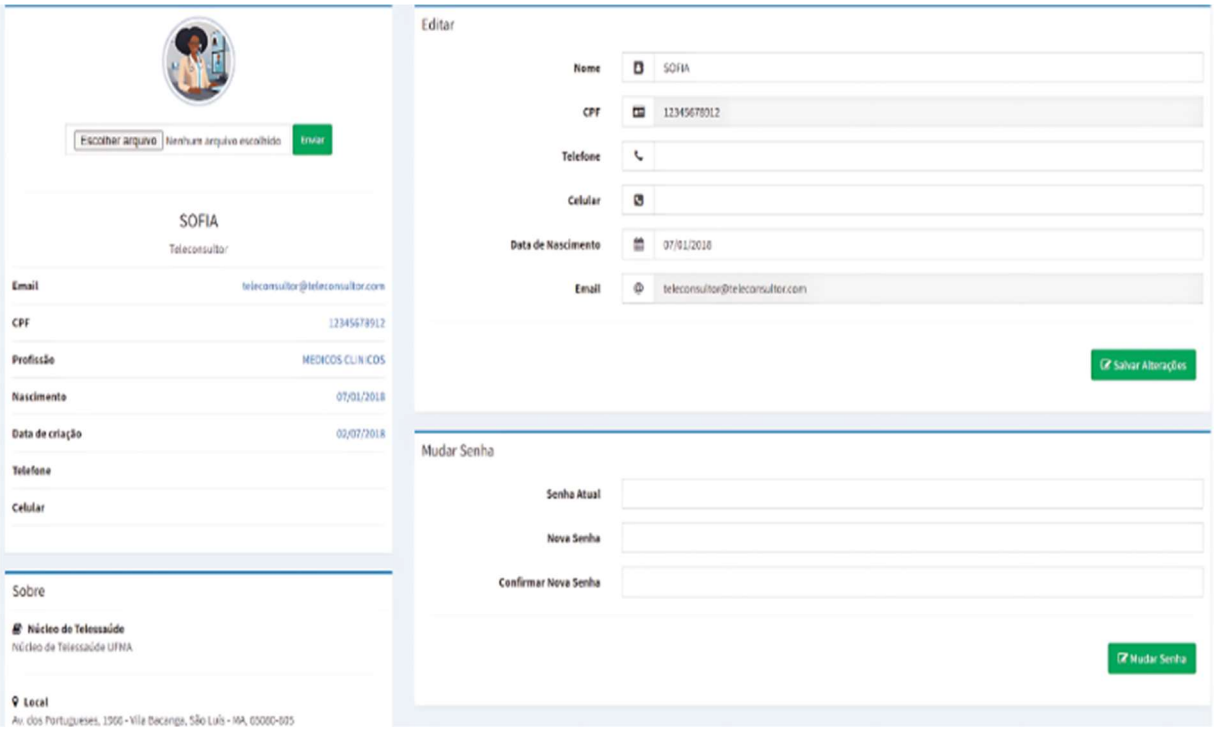
Another timed feature is the verification of active and inactive profiles on the platform. If a user has not made a request for more than 90 days, the profile will automatically become inactive by SOFIA, and this verification is performed daily.

In addition to automatically updating the progress of teleconsultations and access profiles, SOFIA is tasked with notifying users after receiving a response. When the request is answered and received by the user, SOFIA sends an email notifying them that the response is awaiting reading. If the response is not read within 10 days of receipt, the user is notified again. However, if the user has not yet read the response, SOFIA will send an email with different content warning that the teleconsultation may expire, sending it 20, 25, 28, and 29 days after receipt, and it will expire on the 30th day.

User profile impersonation

SOFIA also can edit some user profile information, password, and the possibility of uploading a visualization avatar (Figures 1 and 2).

Figure 1 - User profile editing form in SOFIA



ISSN: 2175_2990 | Latin Am J telehealth, Belo Horizonte, 2023;10(3): 239 - 252

Figure 2 - Example of profile with customized image

Applicant Features

As a requester, the user can enter a question by inserting free text, along with files (e.g. exams) that aim to complement the question. If the request is not complete, the requester can save it as a draft for later submission, as shown in Figure 3.

Figure 3 - Screen for the requesting healthcare professional to describe the query, with options to save as a draft or send the request to the Center

If the requester's query is about a specific patient, he/she can provide the CPF and, automatically, the data on the SUS National Card, date of birth and mother's name, as shown in the figure below, are searched in the DataSUS database, with a view to possible regulation of the case.

Figure 4 – Screen for entering patient data, if necessary.

To organize teleconsultations, the division into different inboxes was adopted. The boxes are: **Answered** - they are the requests that have already been answered by the Telehealth Center; **Returned/Cancelled** - requests that were returned for the requester to enter new data that may help to provide a better response, or teleconsultations that are not part of the scope of telehealth and are canceled with due explanation; **Sent** - they are all teleconsultations that were sent by the requester, but have not yet been answered; **Drafts** - the list of incomplete consultations that have not yet been sent by the requester.

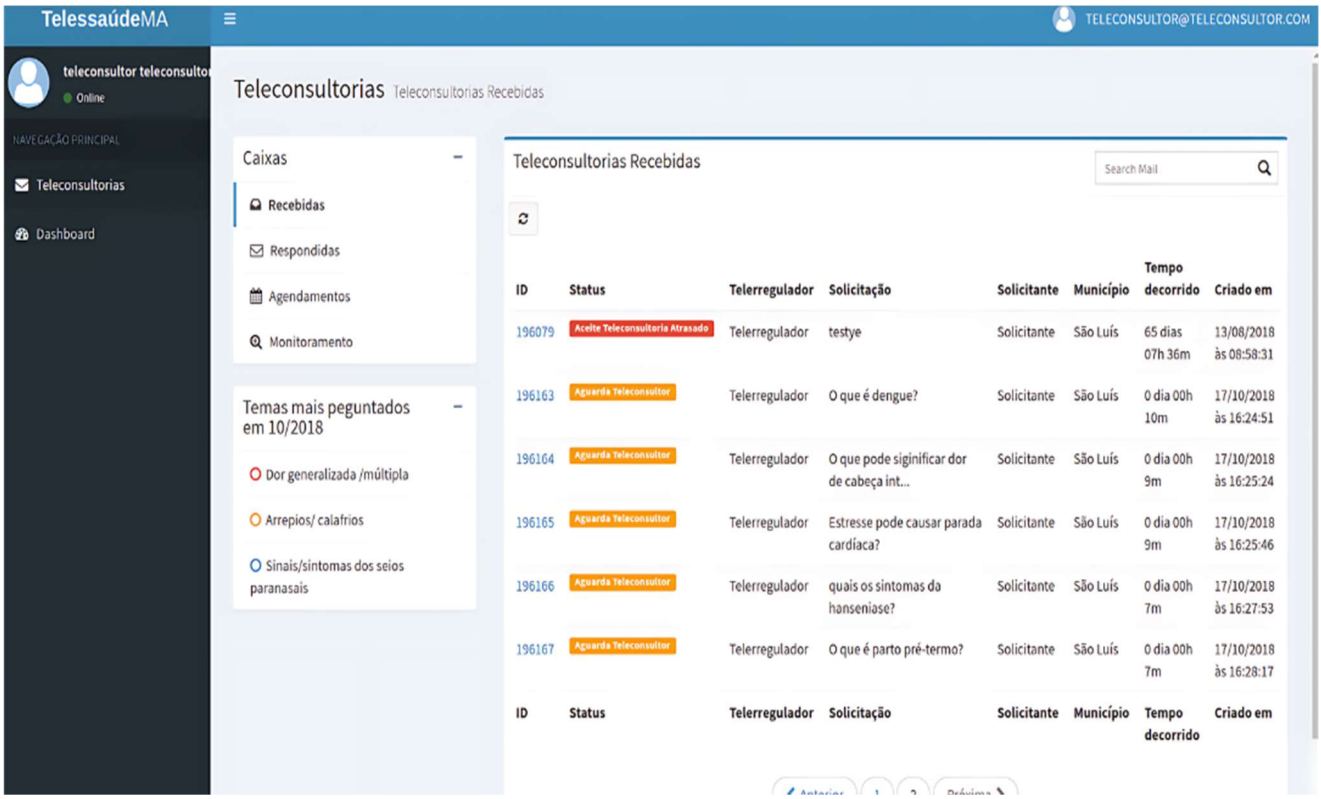
As a requester, the user can also view the three most frequently asked topics during the month, calculated according to the International Classification of Primary Care (ICAP) registered in the process by the teleregulator.

When the teleconsultation is answered, the process appears in the requester's inbox with the status “awaiting reading”. When opening the response, the user can read what the teleconsultant sent and evaluate (feedback from the requester) whether or not their question was answered with the information provided.

Teleconsultant Features

The teleconsultant profile has a mailbox with folders relating to received, sent, and monitored teleconsultations as well as a quick overview of the most asked topics in the month, classified by CIAP.

Figure 5 – Presentation of the teleconsultant profile screen, mailbox with folders

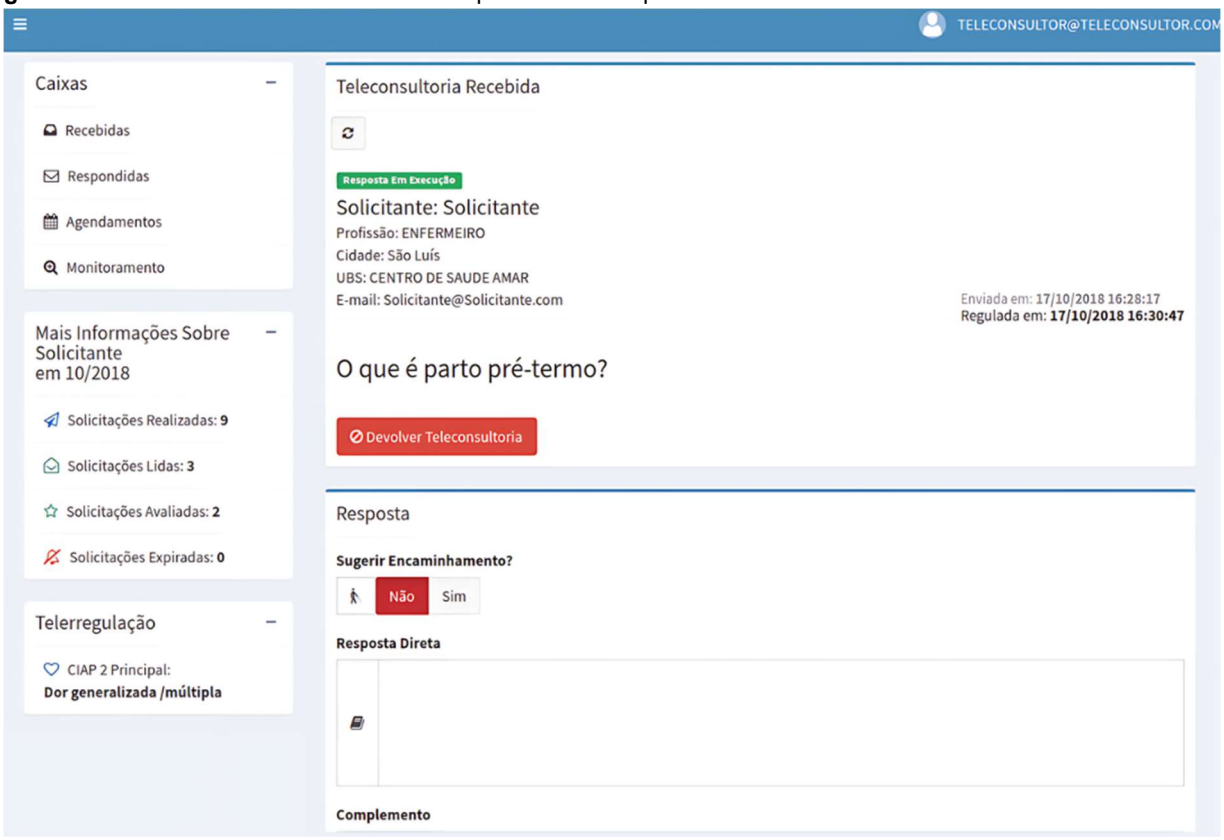


ISSN: 2175_2990 | Latin Am J telehealth, Belo Horizonte, 2023;10(3): 239 - 252

The **Received** inbox lists all teleconsultations forwarded by the teleregulator for the teleconsultant to accept and prepare responses; **Answered** shows all teleconsultations answered by the teleconsultant; the **Monitoring** panel offers an overview of all teleconsultation processes carried out by the center in which the teleconsultant is registered.

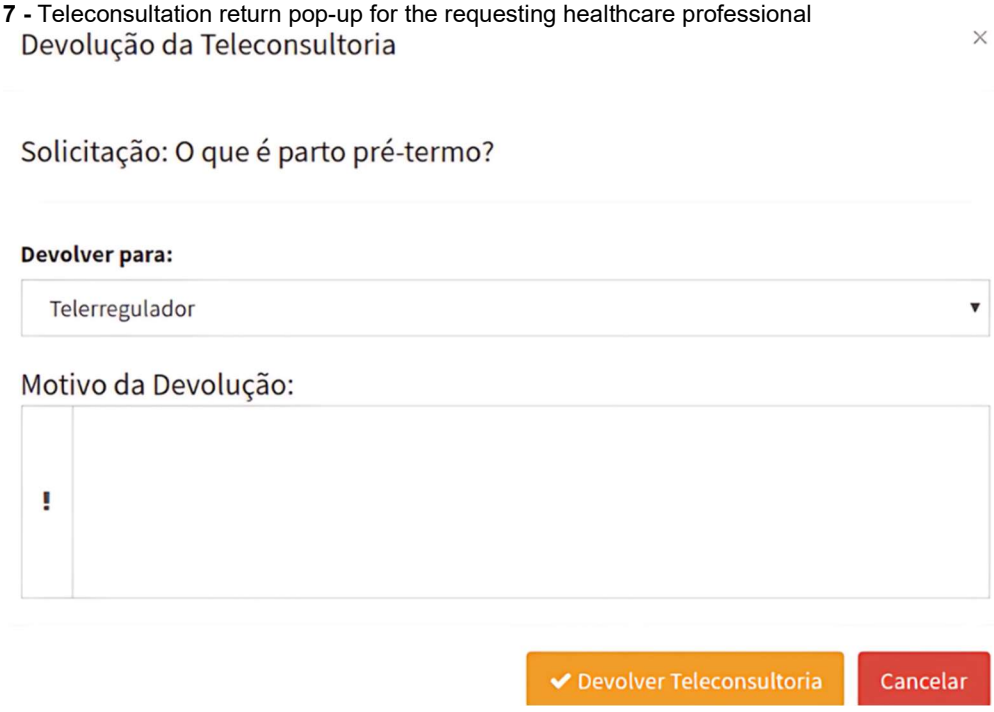
When opening a teleconsultation from the Inbox, the teleconsultant expresses interest in accepting to respond to it. After this action, the teleconsultancy is enabled for response and a screen appears with text boxes for creating the response, the possibility of drafting, additional information about the applicant, information provided by the teleregulator, the possibility of attaching files, indication for SOF and suggested forwarding.

Figure 6 - Screen with the teleconsultation response form template



The teleconsultant also has to return the teleconsultation to the teleregulator or requester if there is any lack of information or problem with the question received.

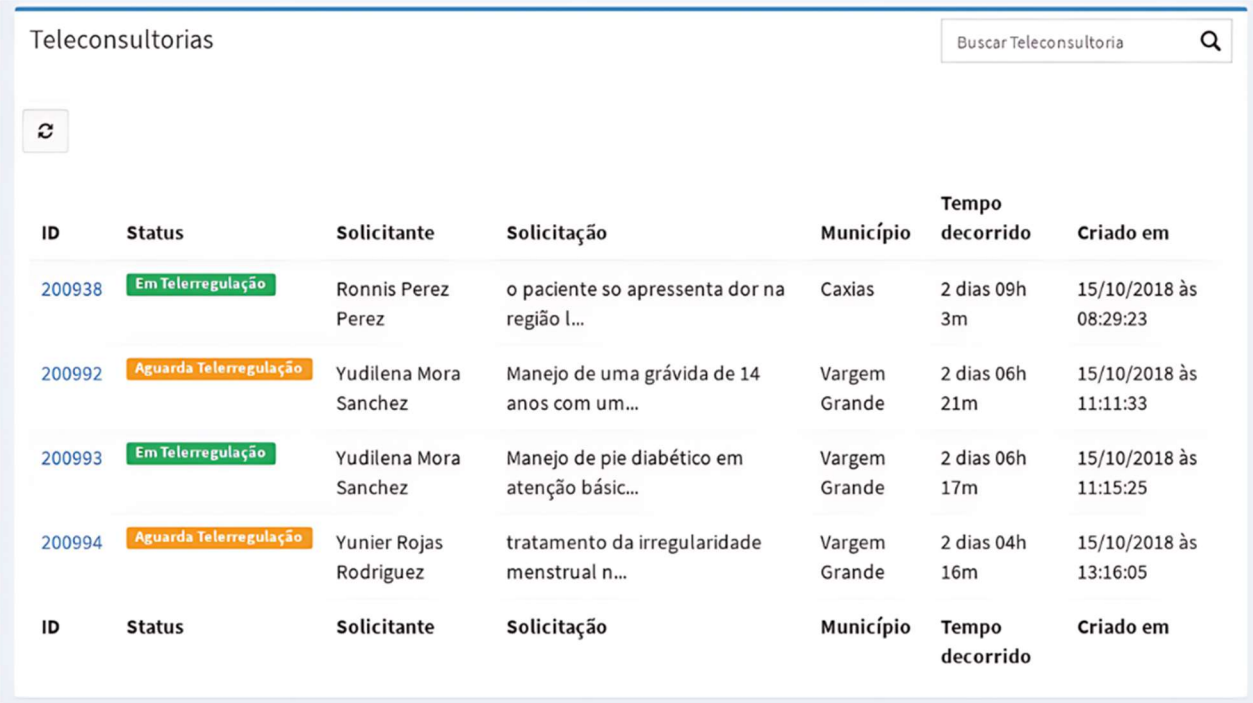
Figure 7 - Teleconsultation return pop-up for the requesting healthcare professional



Teleregulator Features

The regulator is the user responsible for screening and forwarding the teleconsultation to the competent professional.

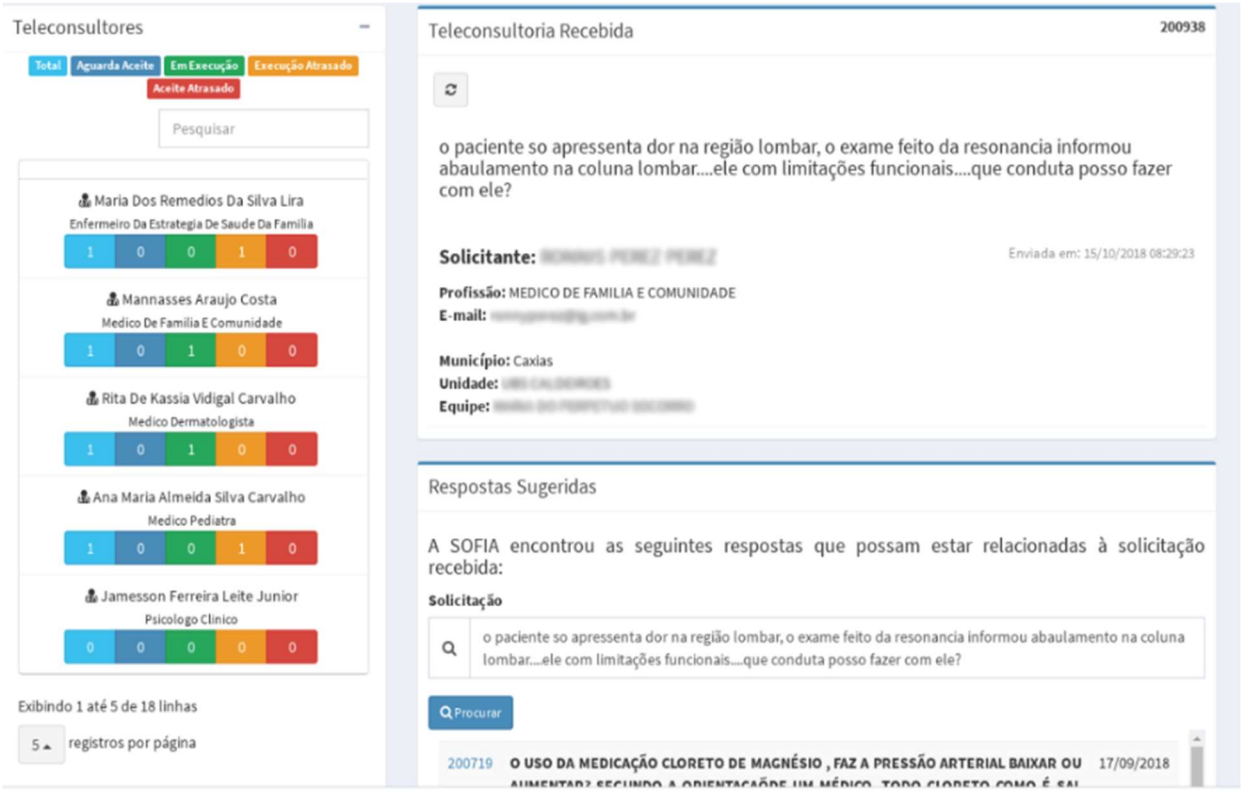
Figure 8 - Home page presentation screen with a list of all requests to be regulated (regulation process)



During the regulation process, the professional can monitor the availability of teleconsultants using the tab on the side, with information on the number of teleconsultations and possible delays per teleconsultant.

The teleregulator can return a teleconsultation to the requester with the option of editing, for corrections to prevent the request from being canceled due to an error during the preparation process.

Figure 9 - Side tab shows the availability of teleconsultants to respond to new teleconsultations



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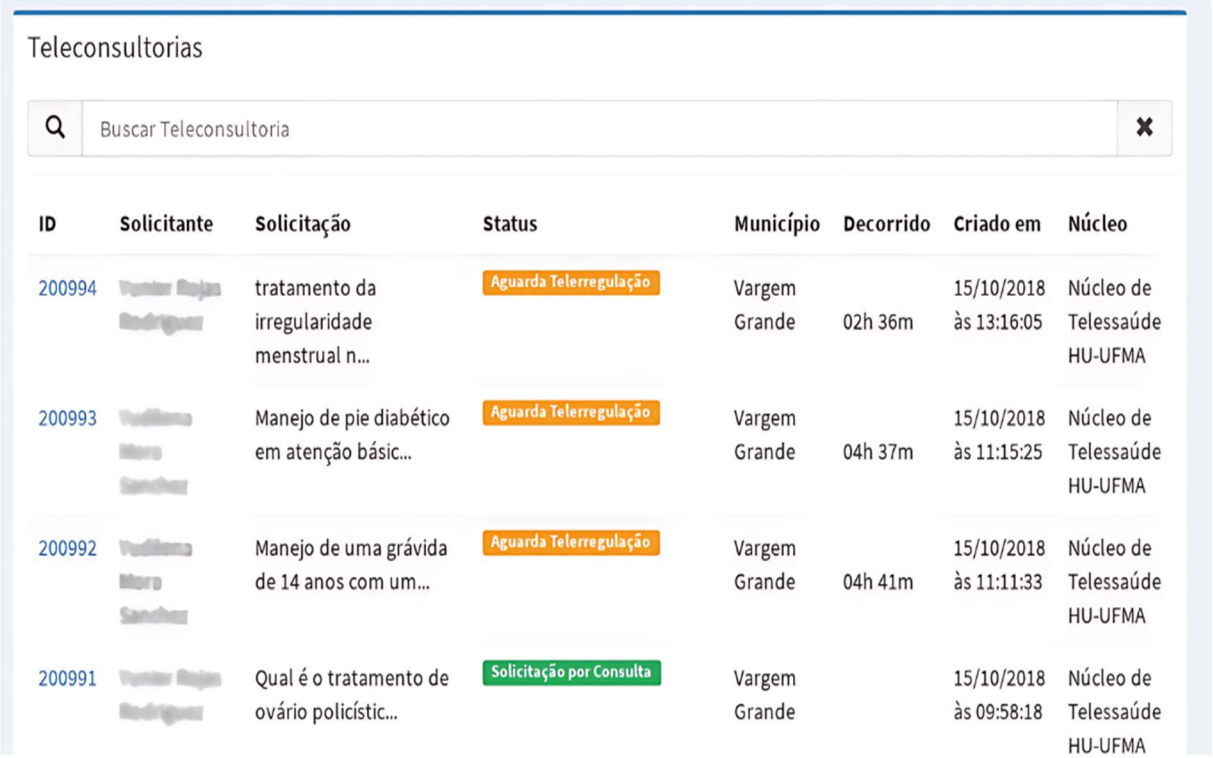
Administrator Features

The administrator is the user with the most functionality on the Platform. The profile has access to all teleconsultations and the maintenance of all registered data, having permission to perform the following functions:

Figure 10 - List of all teleconsultations by Telehealth center registered in SOFIA.

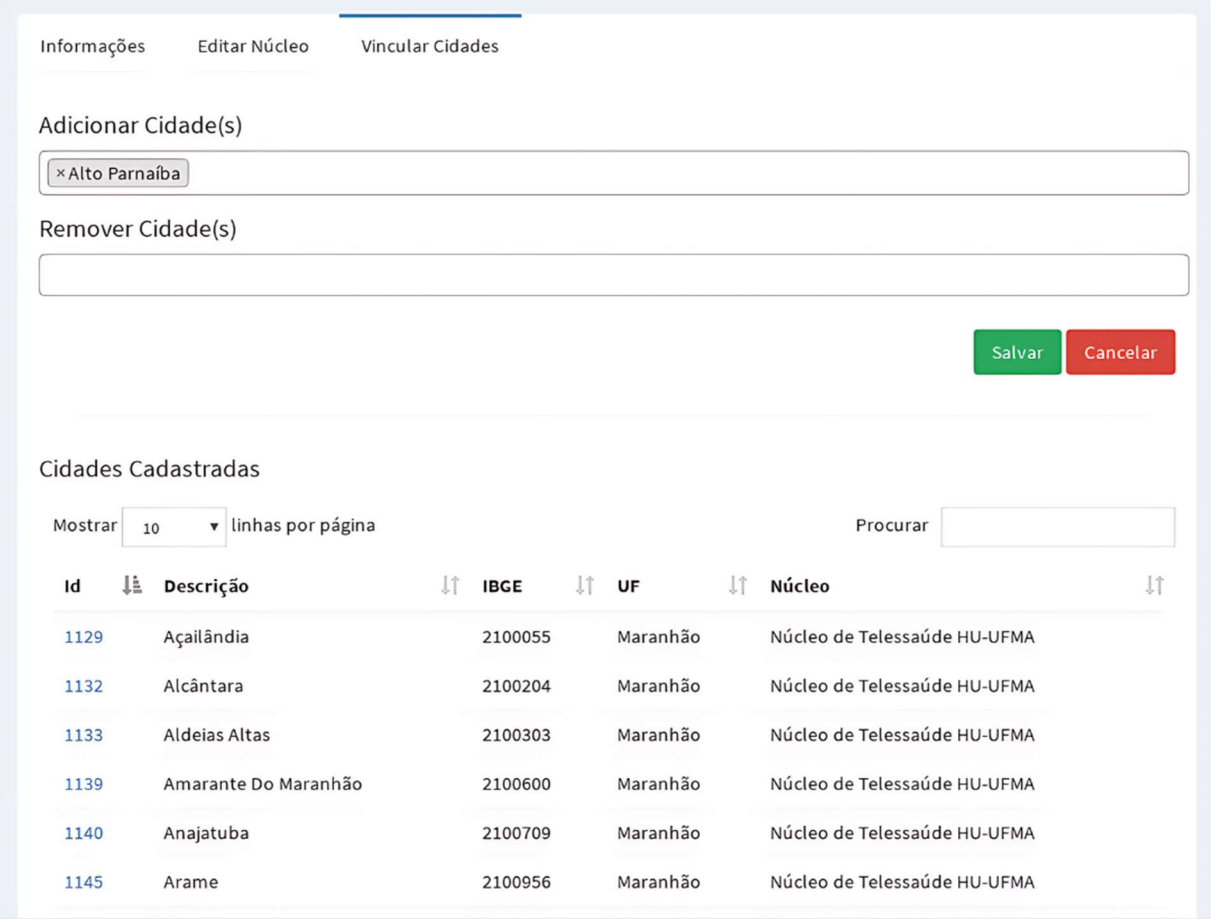


1. Maintenance (addition, editing, and removal) of Telehealth Centers (the platform was designed to run different centers in a single application).

Figure 11 – List of Telehealth Centers registered in SOFIA

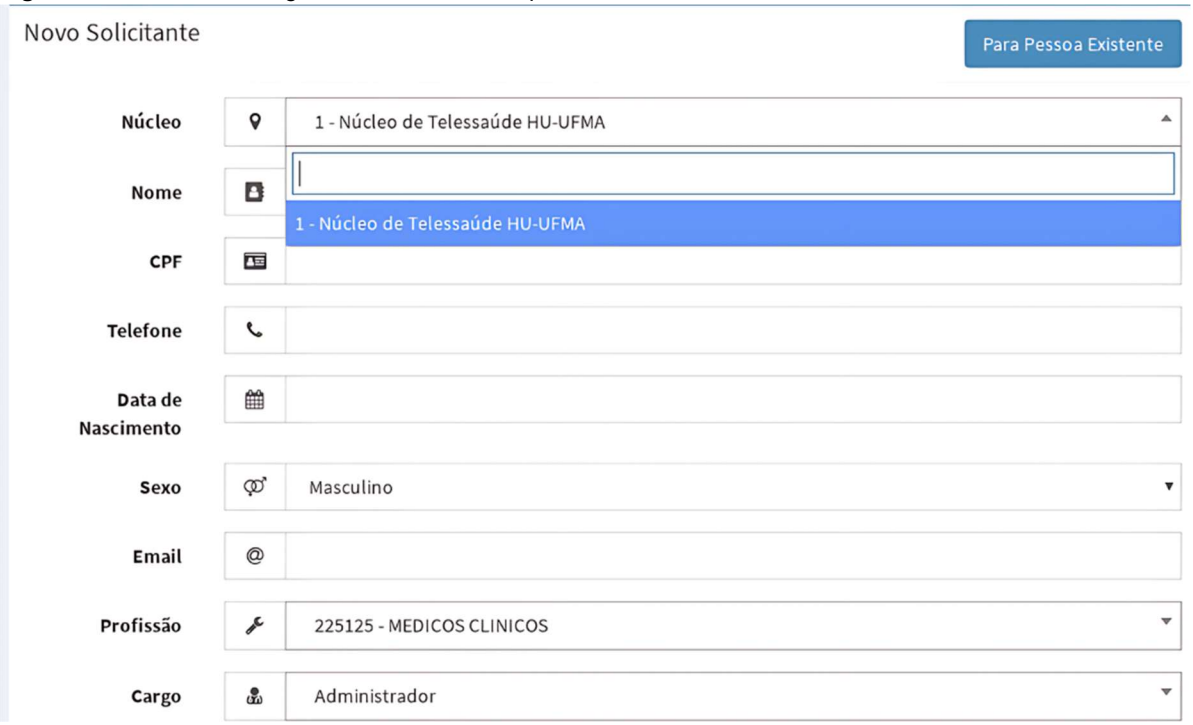
2. Maintenance (addition, editing, and removal) of all cities linked to the registered centers.

Figure 12 - List of cities registered by Telehealth Center



3. Maintenance of all users (Administrator, teleregulator, teleconsultant, applicant, technical-administrative, and local supporter) registered on the platform.

Figure 13 - List of users registered on the SOFIA platform



4. Maintenance of all basic health units registered on the platform.

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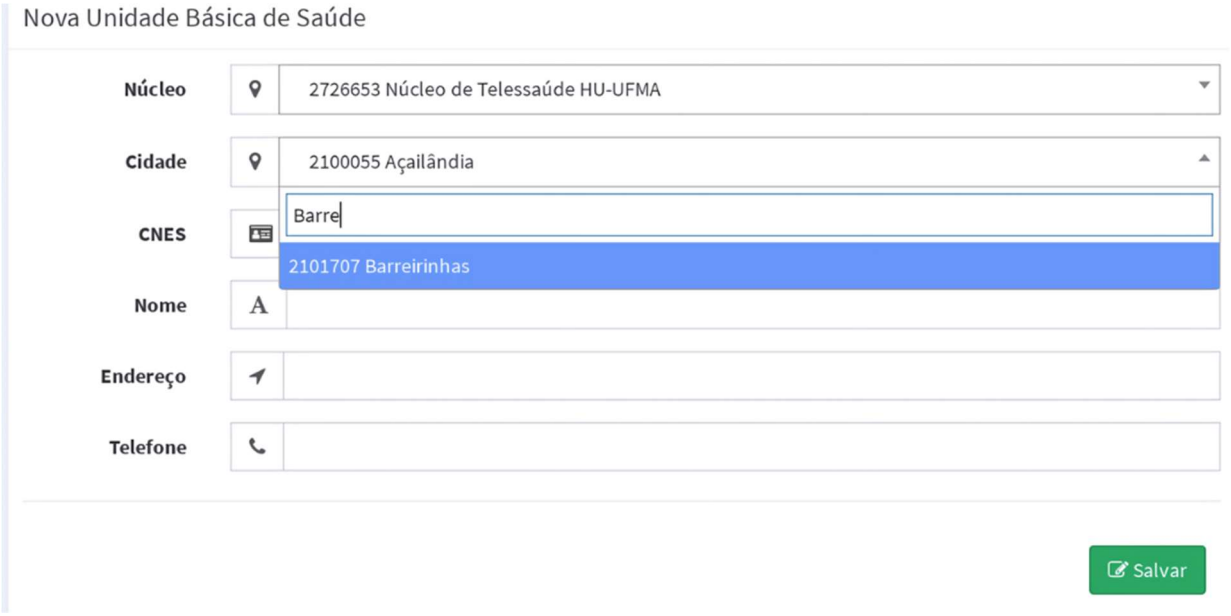
Figure 14 - List of basic health units registered on the SOFIA platform



5. Maintenance of all primary care teams registered on the platform.

Figure 15 – List of all primary care teams registered on the SOFIA platform

Local Supporter and Administrative Technician Features

The Local Supporter and the Administrative Technician perform functions that assist in maintaining the program's structural data, such as: registering and maintaining users, teams and units involved. In other words, these are functionalities inherited from the Administrator profile, however, with specific restrictions.

- Local Supporter

This profile is an extension of the applicant profile. In the cities where the program is implemented, applicants are voluntarily committed to helping monitor and insert new users, teams, and units. Therefore, these applicants now have an additional profile that allows them to perform these tasks restricted to their municipality.

- Administrative Technician

This profile has some of the same functionalities as the administrator. However, some restrictions include not being able to edit core information and managing only the structural data of the core to which it belongs.

Alternative flow of teleconsultations using inverted index algorithms

SOFIA also introduced an innovation in the information engineering algorithms, resulting in a new way of responding to requests by reusing more than 29,000 responses already prepared by the Center.

The platform now includes an alternative flow implemented with inverted index algorithms: tf-idf (Term Frequency - Inverted Document Frequency),

which is an algorithm for ordering documents by relevance based on a query term.

In the context of SOFIA, the algorithms were implemented in scripts with the Python programming language, as the best in terms of processing textual data. In total, the following scripts have been implemented so far: **processing.py** - a script that filters the text, breaking it down into words only, eliminating stopwords (words that are not relevant to the search, such as “or”, “that”, “where”, to”, etc.), removing accents and applying the stemming technique (reducing words to a common root, increasing search collisions, which consequently improves the calculation of relevance, such as “cardiologist” and “cardiology” for “card”); **dbConnection.py** - connects to the core database and queries all teleconsultations that have answers and FAQs (Frequently Asked Questions), which are frequently asked questions and answers structured separately; **buildindex.py** - receives data from teleconsulting and FAQ and creates two data structures, in jSON format, that store relevant information for later search calculations; **engine.py** - calculates the weights and relevance of words for each document (consulting and FAQ) using a mathematical formula that returns the list ordered by relevance of the search term; **search.py** and **faq.py** - direct the search term to the indexes of the consulting and FAQ databases, receiving the search term as an argument in the call.

Figure 16 - Calculation of relevance of a document from a query (tf-idf algorithm)

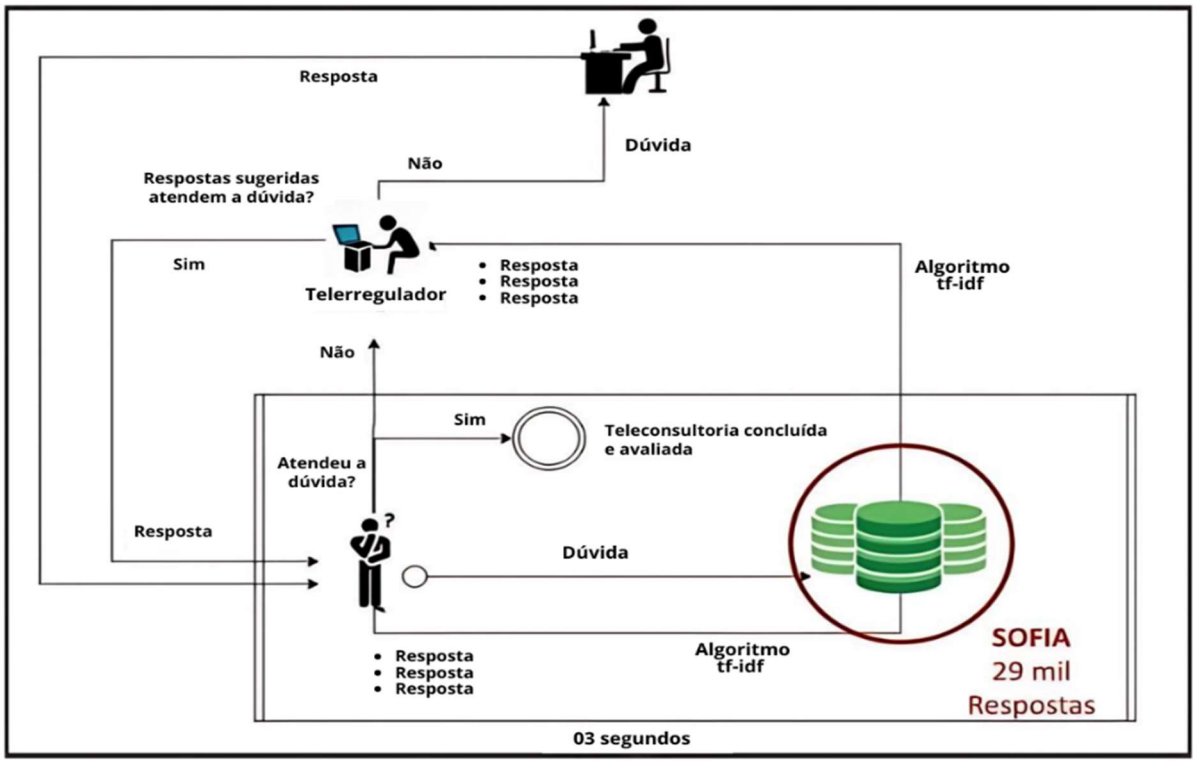
$$w_{i,j} = tf_{i,j} \times \log\left(\frac{N}{df_i}\right)$$

$tf_{i,j}$ = number of occurrences of i in j
df_i = number of documents containing i
N = total number of documents

The search engine with the above scripts is now in version 2, where efforts have been made to improve calculations of relevance and speed in searches and to enhance the user experience. With the entire algorithmic process being carried out by the team's so-called Python helpers, integration with SOFIA and the creation of a new flow has begun, which now allows users to obtain relevant responses in much less than the 72 hours recommended in a resolution by the Ministry of Health[9].

The functionalities based on the search engine were inserted into the teleconsultation sending flow (requester) and the teleregulation flow, creating an alternative flow for receiving responses, which has already been showing good results[10,11].

Figure 17 - Alternative flow created with the help of inverted index algorithms



With the creation of the new flow, the requester, instead of posting the question directly, is redirected to a new screen. On this screen, the requester informs the question and SOFIA uses the tf-idf algorithm to search the database, which contains more than 29 thousand answers, for the most relevant ones, which may have the answer to the question informed. This result is shown in less than 3 seconds. The requester then can check the answers and, if one of them satisfies the question, the requester can select that answer and evaluate it, closing the teleconsultation flow. If none of the answers offered by SOFIA satisfy the requester's question, the requester continues with the flow normally, posting his/her question on the platform.

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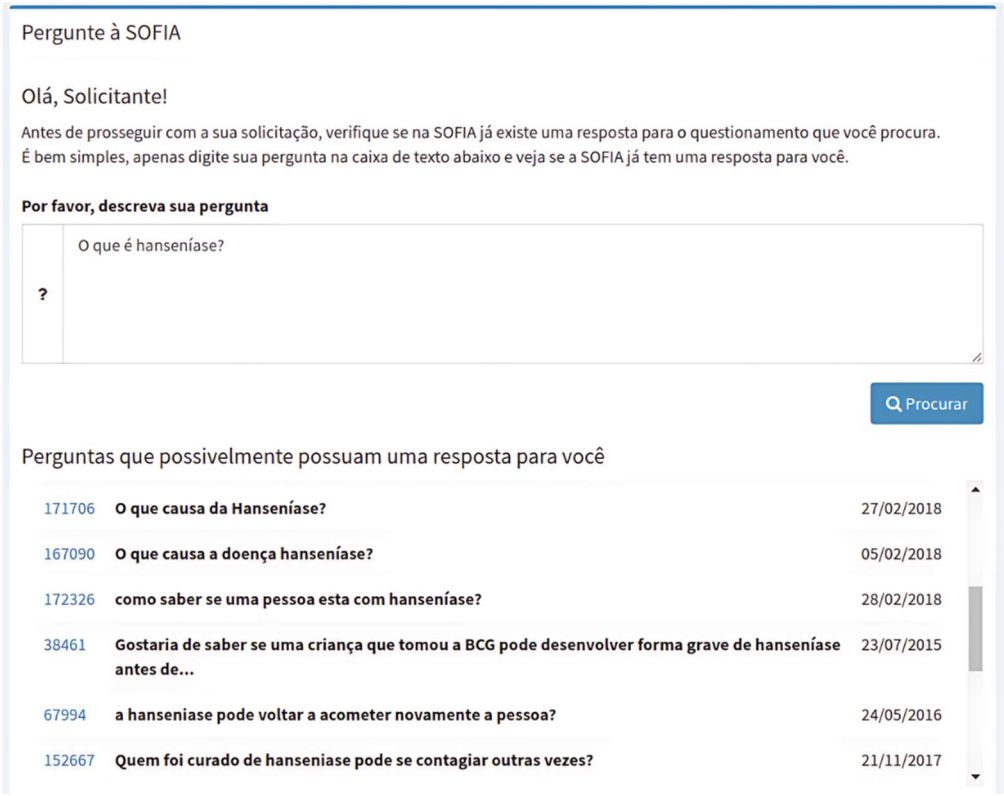
Figure 18 - View screen of the requesting healthcare professional with suggested answers relevant to the question

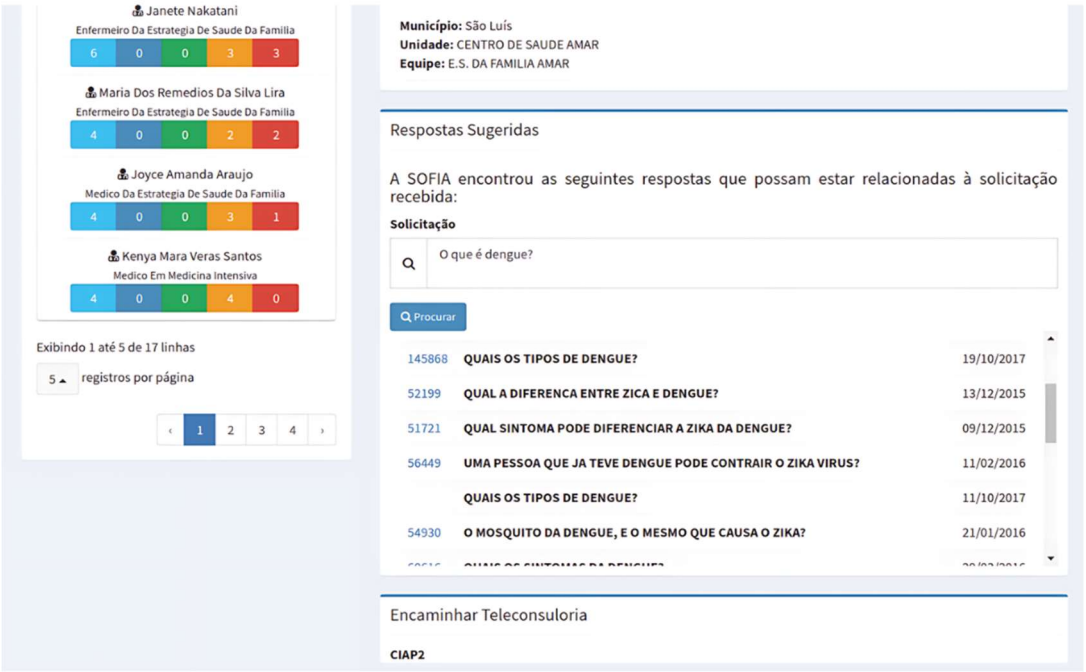


However, the requester often receives a list of relevant answers but ends up sending the question anyway. Because of this, the tf-idf algorithm is also used in the teleregulation process. Now, upon receiving the question, the teleregulator already obtains a list of answers that may satisfy the question, and can then choose one of them and send it directly to the requester.

In addition, the teleregulator can simplify the question through editing to improve the calculation of relevance. However, these changes are not made directly in the database, maintaining the text of the original request.

If, even so, through these processes, no relevant answer is found, the teleregulator sends the question to a teleconsultant, continuing the conventional flow.

Figure 19 - Teleregulator view screen showing suggested answers to the requesting healthcare professional's question



SOFIA's Challenges and Future

Despite the numerous benefits, the implementation of SOFIA is not without its challenges. The adaptation of professionals to the use of new technology, the need for continuous maintenance and updating of the database, and the guarantee of security and privacy of information are aspects requiring constant attention.

However, the future of SOFIA is promising. With plans to expand to other areas of health and the continuous improvement of its functionalities, the platform has the potential to become a model for similar initiatives throughout the country, consolidating the role of artificial intelligence as an indispensable ally in the digital transformation of public health.

The implementation of SOFIA in PHC has generated significant impacts on the quality of care provided. Health professionals report greater confidence in clinical decisions and a reduction in the number of unnecessary referrals to higher levels of care, which contributes to the efficiency of the health system as a whole.

In addition, the platform has played a crucial role in the continuing education of professionals, promoting a culture of continuous learning and constant updating, essential elements for evidence-based clinical practice.

CONCLUSION

SOFIA exemplifies how technological innovation can be effectively applied to solve complex challenges in public health. By leveraging artificial intelligence to provide fast and accurate answers to healthcare professionals' questions, the UFMA Telehealth Center platform not only improves the quality of care in PHC but also strengthens professionals' ability to act in an informed and confident manner. In a healthcare system as vast and diverse as the SUS, initiatives like SOFIA are essential to promote efficiency, quality, and equity in healthcare.

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Statement of Responsibility: We hereby declare that we participated in the development of the work titled “Sofia: pioneering and innovation in the telehealth brazil network program” and assume public responsibility for its content.

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Funding: We hereby declare that the work titled “Sofia: pioneering and innovation in the telehealth brazil network program” did not receive any type of funding or financial support from public, private, or institutional sources.

Conflict of Interest: We declare that there is no conflict of interest regarding this research, authorship, or publication of this work that could influence its objectivity or integrity.
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How to cite this Article: Serra HO, Moreira GS, Maia LB, Maia AB, Nascimento CGM, Silva RS, Nunes VF, Araújo AR, Penha LG, Lima NS, Oliveira LA, Neves ACFB. SOFIA: Pioneering and Innovation in the Telessaúde Brasil Redes Program. Latin Am J Telehealth, Belo Horizonte, 2024; 10(3): 239 - 252. ISSN: 2175-2990.