An Architecture to Identify Aromatic Herbs using Augmented Reality (AR) and Mobile Application

JOÃO CARLOS LOPES FERNANDES[a], MARCELO TSUGUIO OKANO[b],
WILLIAM APARECIDO CELESTINO LOPES[c], SAMIRA NASCIMENTO ANTUNES[d],
ODUVALDO VENDRAMETTO[e]
Department of Production Engineering,
Paulista University - UNIP,
São Paulo,
BRAZIL

[a]ORCiD: 0000-0002-5309-6304
[b]ORCiD: 0000-0003-1680-7821
[c]ORCiD: 0009-0009-4437-776X
[d]ORCiD: 0000-0001-9813-1874
[e]ORCiD: 0000-0003-2430-6138

Abstract: - Mobile applications are part of people's daily lives, helping with many daily tasks. The objective of this article was to create an architecture for identifying aromatic herbs in a CEAGESP food distribution center through an application integrating augmented reality and computer vision technologies. The methodology used to develop the article was a case study applied at CEAGESP using the proposed architecture to identify aromatic herbs and evaluate the benefits of practical implementation. This proposal aimed to meet a growing demand for solutions that help consumers distinguish herbs that share morphological similarities, such as similarities between leaves and stems, a challenge for selecting and purchasing high-quality products. The design and implementation of this architecture allowed the superimposition of virtual information on the identified natural environment, containing an intuitive and easy-to-use mobile application. Users could visually scan products and receive detailed information in real-time using a comprehensive database of aromatic herbs and their distinctive characteristics. Upon completion of the architectural steps applied to the project, it was possible to verify the presentation of aromatic herbs on the application screen, making it clear that they worked with precision. The study of the architecture associated with the development of the application allowed the identification of 18 types of aromatic herbs with quick response times and safe results for users. This functionality increases consumers' confidence in purchasing decisions while facilitating the accurate identification of aromatic herbs that might otherwise be confused due to morphological similarities.

Key-Words: - AR, augmented reality, mobile, App, aromatic herbs, CEAGESP, herb.

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1 Introduction

The growing demand for food is a global reality due to the current population increase. To equalize this problem, a good strategy is to reduce waste; for this, technological artifacts that identify the types and species of food are a viable solution, [1].

Most food waste occurs in the preliminary stages of the supply chain and is often related to the absence or deficiency of infrastructure and post-harvest systems. In contrast, food waste occurs in the later stages of the chain, such as the retail market and consumption, and is always related to human behavior, [2].

Every year, around 14% of the food produced is lost between when it is harvested and when it reaches stores. Furthermore, producers and consumers end up wasting another 17%. Food loss and waste also contribute to the climate crisis, accounting for up to 10% of global greenhouse gas emissions, [3].

Brazil occupies the third position among fruit and vegetable producers worldwide, with around forty-five million tons produced annually, offering tropical and temperate fruits throughout the year. However, losses and waste occur during all stages of the production chain, [4].

Digital technologies bring new resources and capabilities when launching new versions or updates of their products or services. In this case, they can speed up the identification of fruits and vegetables, minimizing losses and waste, [5].

In this article, we propose an architecture based on augmented reality and the use of a mobile application to identify eighteen types of aromatic herbs sold by retailers from Companhia de Entreposto e Armazéns Gerais de São Paulo (CEAGESP), an institutional and academic partner in the sector Project.

CEAGESP is a federal public corporation linked to the Ministry of Agrarian Development and Family Agriculture and represents an essential link in the horticultural products production chain, [6].

Owner of the largest public warehouse network, CEAGESP contains silos (large cylindrical warehouses for storing agricultural products) and bulk carriers (places that receive or house products in bulk) in the State of São Paulo, totaling twelve active units distributed throughout the state of São Paulo. São Paulo. São Paulo, [7]. The structure of the storage company can be seen in Figure 1.

Fig. 1: Representation in the top view of CEAGESP. Source: grouped by the authors based on source, [7]

2 Literature Review

2.1 Augmented Reality and Its Applications

Augmented Reality (AR) is the superimposition of virtual objects in the natural environment through a technological tool that improves or increases the user's vision, [8], [9], [10].

The application of AR presents several studies with successful use, including in the entertainment industry, particularly in electronic games and simulation environments, among other application alternatives, [11].

The first reference to AR occurred in the sixties, more precisely in 1964, when Sutherland published his doctoral thesis entitled "Sketchpad, a Man-Machine Graphical Communication System." However, it was only in the 1980s, with the help of the military, that the first AR project took place, which was the construction of an airplane cabin simulator using virtual elements with the users' physical environment, [10], [12].

With the help of technological devices, AR can provide a superimposition between digital objects within physical environments in real-time, improving or increasing users' vision, [10], [12]. For this to happen, computer vision and computer graphics techniques must be combined, [8].

User interaction with virtual elements must be characterized by its naturalness and intrinsic safety since digitally generated content overlaps with the physical environments in which users are inserted. This overlay is a complement to reality, not a complete replacement, and this process can be made possible through cameras integrated into mobile devices, such as smartphones, thus eliminating the need to use specific equipment, [13].

Augmented reality has great versatility, one of whose applications is the association of an object detection system with neural networks to obtain a quick method for building a data set of specific objects, [14].

The relationship between technology and herbs can be integrated through an augmented reality application to define the characteristics and uses of local herbs by using animations, [15].

Another study that relates mobile technologies to food is the solution to distinguish medicinal herbs through leaves and flowers using deep learning algorithms and image processing through a mobile application. The proposed mobile application identifies a flower and a leaf by their morphological characteristics, such as shape, color, and texture. This application combines 3D models of medicinal herbs with augmented reality, [16]. When including a subsection you must use, for its heading, small letters, 12pt, left justified, bold, Times New Roman as here.

2.1 The Importance of Identifying Herbs in the Environmental Context

The versatility of aromatic herbs transcends their natural consumption and is applied in post-processed products such as essential oils and dietary supplements, [17].

Facing the challenges of identifying types of aromatic herbs becomes vital due to their characteristics suffering from climate change, conservation conditions, vast diversification, and innovations applied to herb derivations. Adopting strategies that make it easier to meet consumer demands during product selection guarantees access to quality products and accuracy in their processing objectives, [18].

The similarities between aromatic herbs often make identification difficult for consumers who do not constantly interact with the appropriate plants. Even though there is a similarity in format and color, the flavor and tasting factors vary according to each species. For some people, changing herbs while eating can cause side effects such as olfactory dysfunction and allergic disorders, [19].

Speed and accuracy in identifying aromatic herbs help professionals who work with the development of plant derivatives, such as their use in essential oils and herbal medicines created for personal consumption on a commercial scale, [17].

The intentional adulteration of aromatic herbs using dyes and salts interferes with the palatability of the food by transmitting sensations. It reduces the efficiency of the conservation delay when associated with other foods. Creating technological tools to combat plant adulteration brings significant gains to food safety. The field of application is vast due to the large number of varieties sold in distribution centers worldwide, [20].

Using technologies associated with aromatic herbs allows us to identify and classify plants according to type, characteristics, and applications, in addition to checking whether the food sold is by the standard distributed in the region and whether it presents physical characteristics that will not compromise its consumption in the future, [21].

3 Methodology

To generate the first MVP, that is, a Minimum Viable Product to be used at CEAGESP (Companhia de Entreposto e Armazéns Gerais de São Paulo), the Design Science Research (DSR) methodology was used, a scientific study to create technological artifacts, [22].

The objective of the methodology is to solve practical problems and is divided into five stages, ranging from development to validation by experts in the field, [23]. The DSR steps contained in the framework can be observed, as shown in Figure 2.

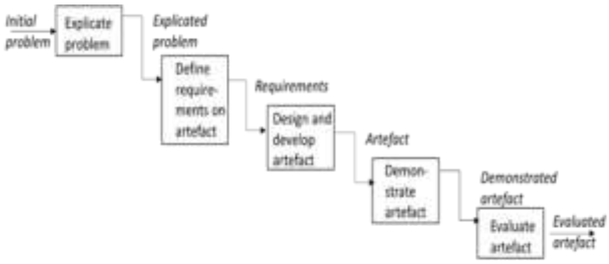

Fig. 2: The structure of the DSR, [24]

Phase 1. Explanation of the problem

The complexity of CEAGESP's fruit and vegetable marketing operation, intermediated by its vast network of 2,800 distributors, involves the transaction of a great diversity of fruits, divided into more than three hundred types, considering the species variations within each category. In addition to this considerable list of fruits, CEAGESP also deals with a significant volume of vegetables and other associated products.

Among the products sold, the group of eighteen main aromatic herbs deserves to be highlighted, namely Rosemary, Leek, Chives, Coriander, Dill, Fennel, Tarragon, Mint, Laurel, Basil, Marjoram, Nira, Oregano, Parsley, Celery, Sage, and Thyme, [25]. The publication book can be seen in Figure 3.

Fig. 3: Printed aromatic herb report, [25]

Trading operations face a significant challenge in quickly and accurately identifying these products during the transaction process. Accuracy in this identification is essential to guarantee customer satisfaction, minimize losses and waste, and improve the efficiency and quality of services offered by CEAGESP.

In this context, the lack of an efficient aromatic herb identification system is a relevant obstacle, promoting the need to develop a solution that can improve the identification and handling of the eighteen main aromatic herbs and contribute to reducing environmental impact. The impact resulting from waste is in line with the principles of sustainability and efficiency that guide operations.

Phase 2. Defining MVP requirements

To create the first artifact or Minimum Viable Product (MVP), which was delivered to CEAGESP in September 2023, it was decided to create an APK, Android Application Pack, an application file owned by the company Google intended for the system Android mobile operating system, that is, a computer installation file format.

The first step towards creating the solution considered CEAGESP's needs and the number of items to be computerized, so it was decided to identify Vegetables and, among them, Aromatic Herbs.

This type of product was chosen because CEAGESP already has extensive textual and visual documentation. Among the various products it sells daily, it is the one that presents an identification problem, as the items that make up its subcategory have some similarities between them, which in certain situations makes visual identification difficult (central problem).

This way, a solution that helps identify Aromatic Herbs meets the inherent and justified need to create a primary MVP. This solution can evolve depending on the new control needs of CEAGESP products.

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When citing references in the text of the abstract, type the corresponding number in square brackets as shown at the end of this sentence, [1].

The authors are required to look over and verify whether the in-text citations exist in the reference list and whether all the references mentioned in the reference list exist in the in-text citations.

Phase 3. Design and development

A flow of activities was created to create the solution, which can be seen in Figure 4, where image capture can occur using three resources: smartphone, digital camera, or webcam, considering the quality of the captured image, which is the main requirement for creating the solution.

Pattern recognition has the function of dividing groups of different elements with repeated symbols, creating a basic form of identification.

To carry out identification, the solution uses augmented reality, user interaction directed by the cell phone camera (Android) to the product, and after identification, information is received on the screen.

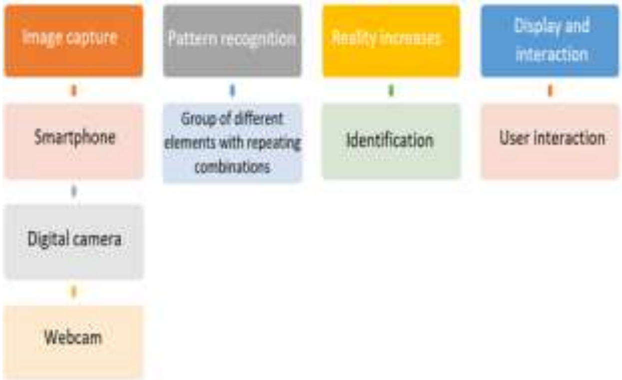

Fig. 4: Solution flow. Source: Authors

The development of the application or APK used Unity software in version 2020.3.33f1, with which it was possible to insert and manipulate the solution images. The C# language programs were also used with the help of Visual Studio in refining the solution.

The solution developed only considers the direct identification of images; it does not use machine learning or Artificial Intelligence techniques, which must be implemented in the subsequences of this project (solution update).

The parameters for their capture and processing must be determined to properly function any computational solution that performs manipulations and simulations with images.

These parameters mark the format, size, resolution, function, and other relevant details of the images that will be manipulated. These parameters must be defined before capture, which is crucial to the solution's success.

To standardize the images used, the following parameters were taken into consideration when collecting the images: the "Image Size," this detail is directly related to the quality and processing capacity of the solution; the "Format," which guarantees that all images can be manipulated in a homogeneous way, "Contrast," which is the difference in brightness between the light and dark areas of the images, is what determines the number of shadows in the image; therefore low contrast images tend to have problems with dimension and smoothness; and "Lighting," which defines the clarity of the image, was also taken into consideration, thus ensuring that the images were equivalent and of good quality.

In the image acquisition phase, the solution's database was acquired. Therefore, the accuracy of image collection is a fundamental factor for identification to occur clearly and safely, reducing possible conceptualization and visualization problems between the selected and analyzed products.

After defining with the CEAGESP team what group and category would be worked on (Vegetables, Aromatic Herbs) for creating the MVP, the collection of images began.

They came from various places and in different formats (jpg, pdf, png, among others) and with non-standard quality; therefore, in some cases, they could not be used.

The collection of images had its first origin in CEAGESP's image bank (images in jpeg and pdf format), which needed more to feed the solution. From this time onwards, the number of images increased, and some images available on the Internet related to the Aromatic Herbs category (respecting copyright) were collected, as shown in Figure 5.

Fig. 5: Aromatic herbs selected from the image bank, [25]

Even so, the number of images needed to be increased for the solution to be effective, meaning that more images needed to be collected. To solve the difficulty, field collections were carried out, considered as technical visits, carried out on some free holidays in São Paulo and at distribution points within CEAGESP itself; that is, more photos were taken to complement and/or replace low-quality photos. Alternatively, that did not meet the requirements defined in the collection.

After obtaining the images, it was necessary to classify them according to the defined parameters, which calibrated the solution.

For this classification, we selected images of excellent quality that are suitable for use. A scale was used to measure the quality of the images represented in DPI (Dots Per Inch).

The higher the image's DPI value, the better its quality. By default, a high-resolution image must be at least 200 DPI, but simply selecting images by DPI amount is not enough, as other details must be considered, to ensure that all photos meet the minimum requirements for the solution, it was decided to use software that classified them.

To choose the images that made up the solution, we chose the Vuforia software version 10.11.3, with which it was possible to identify the characteristics in each image.

Vuforia evaluates images on a scale ranging from 0 (zero) to 5 (five), where zero means low-quality image and five means high-quality image.

The choice to use Vuforia is due to the easy integration with Unity, another tool used in creating this solution.

Therefore, it can be guaranteed that the MVP delivered to CEAGESP only has images qualified with parameter 5 (five); this choice was intuitive to reduce as much as possible the occurrences of "false positives"; that is, the identification fails or even indicates a wrong result.

Figure 6 shows how the images are classified by Vuforia, in which it is possible to observe the number of stars. They indicate the quality of each image, that is, without stars, low quality, and when the flag indicates 5 (five), it represents the maximum quality; between 1 (one) and 4 (four) stars, the images have exponentially increased quality.

The development of the application was divided into two stages, the first being the backend and later the frontend, two fronts. Given this scenario, the structure, and details of the development of activities follow.

The first step in developing the backend and operationalizing the application was the structural organization of the information with the creation of folders corresponding to the different types of aromatic herbs to be identified. Each folder contains images of specific species, establishing a basis for future comparative analysis.


Aromatic Herbs
Type:

Target name	Type	Assessment
SALVIA_2	Image	☆☆☆☆☆
LOURO_1	Image	☆☆☆☆☆
ALHO_PORO_1	Image	☆☆☆☆☆
ERVA_DOCE_1	Image	☆☆☆☆☆
HORTELA_1	Image	☆☆☆☆☆
SALSAO_4	Image	★★★★★
NIRA_6	Image	★★★★★
SALSA_6	Image	★★★★★
HORTELA_7	Image	★★★★★
ALHO_PORO_2	Image	★★★★★
ESTRAGAO_6	Image	★★★★★

Fig. 6: Image selection.
Source: Authors

The second step was classifying images in the Vuforia database, allowing the system to understand and relate the images considering their geometries and contrasts, thus facilitating subsequent identification.

In the third step, an additional folder is created for each of the eighteen species of aromatic herbs to be analyzed. These folders store the reference images that will be compared with those captured by the mobile device's camera. This comparison is essential for accurate species identification.

The fourth step consists of inserting the previously organized folders into the "Assets" environment of the Unity software, the development platform used to create the application. This ensures all necessary information and resources are available to build the application's user interface and logic.

The fifth step involves integrating the Vuforia Engine AR package into Unity. The Vuforia Engine provides image tracking and marker technology, allowing AR to work effectively. Its integration is essential for detecting and superimposing virtual information on authentic images of aromatic herbs.

Finally, a C# script is developed for the Unity application in the sixth step. This script references information about a specific image, its location in the Vuforia database, and the image displayed after using the application. This includes details such as the species name of the aromatic herb, its description, and additional information relevant to identification. The script acts as a bridge between the data and the user interface, enabling a fluid and informative user experience.

The presentation screen was initially thought of to develop the front end. The application starts with a splash screen that plays an essential role in communicating with the user. This screen displays the partners involved in the development of the application. Collaboration between the institutions was fundamental to the project's success, and, therefore, the inclusion of the logos and names of the partner institutions conveys credibility, in addition to reinforcing the commitment to the quality of the application.

In the second stage of the front end, the application name and logos were inserted into the usage screen, highlighting the importance of collaboration, and providing helpful information to the user about the entities involved in the development of the application.

An essential feature of the application is the provision of additional information, which is included in the third stage. To do this, a button was inserted that directs the user to the CEAGESP website, where they can download the PDF version containing detailed information about aromatic herbs. This gives the user a reliable reference source, expanding their knowledge.

In the center of the application screen, a guidance message was inserted to assist the user in the fourth step of the front end. The phrase "Point to the aromatic herb you want to identify!" highlights the interactivity of the application and guides the user on how to use the application's main functionality, which is the identification of aromatic herbs through the mobile device's camera. The result obtained can be seen in Figure 7.

Fig. 7: Application screen. Source: Authors

Phase 4. Testing and Evaluation

In the fifth stage, the application underwent critical testing and validation. Several mobile devices were used to evaluate the application in different configurations and operating systems during this stage. The goal was to identify and fix potential performance, compatibility, and usability issues.

The evaluation also involved collecting feedback from users to assess the effectiveness of the application in its main functionality: the identification and classification of aromatic herbs.

4 Results and Discussion

The application made it possible to verify the difference between the 18 types of aromatic herbs studied. Six hundred images containing the types were analyzed, stored for studies, and captured in the field at the CEAGESP distribution center. After creating the architecture for image recognition, the application indicated an accuracy of 96% of the images tested and a response time of 2 seconds.

The application created to execute the architecture used a device with Android operating system version 8.0 “Oreo” (API level 26) with 8 GB of RAM.

Some difficulties during the execution of the architecture tests were identified, such as the quality of the images used, the lighting of the environment, and the camera angle when handled during identification.

The quality of the images analyzed directly interfered with the calibration between the cell phone camera and the application. The difference between the megapixels of the images captured for analysis and those shared by the CEAGESP database presented discrepancies in identification. Given this scenario, a standardization filter based on computer vision was applied.

The lighting contained in the environment during the capture also interfered with accuracy, as the contrast obtained during image capture between the herbs and the cell phone made it difficult to compare and direct responses.

The incidence of the capture angle during the application's recognition action also showed a positive result when directed at an angle of up to 30° between the herb to be identified and the position of the cell phone camera.

The use of Apple's operating system for cell phones has yet to be implemented, but the version will be developed soon.

Given the accuracy and response time in identifying herbs at the distribution center, the analysis helped with food safety, associating the morphology of the plant with a registered image pattern, and preventing the food from being misused.

It provided greater security for consumers who select plants and use them in food combinations, processing them into oils, and creating herbal medicines.

5 Conclusion

Augmented Reality technology enables users to interact with virtual objects that are part of the real world and, in real-time, are registered in 3D (three dimensions), [26], [27]. AR has enormous potential in creating applications in horticulture. There are few solutions based on computer vision components used in this area. However, many challenges must be faced in research and development efforts in agriculture and its sub-areas.

The system used the overlay of virtual information on the natural environment, providing an interactive and educational experience for users and providing knowledge about aromatic herbs and a deeper understanding of local biodiversity.

The functionality of the architecture where the application was inserted increased consumer confidence during the herb selection process, preventing errors from being seen due to similarities between herbs due to shapes and colors.

The degree of innovation in this study was presented with augmented reality being used to avoid errors in identifying aromatic herbs, in addition to an interactive experience for users. The practical application at CEAGESP represents a significant advance, using technology to monitor the biodiversity of aromatic herbs sold at the distribution center.

The sustainable benefits observed with the application within the architecture helped identify the morphology about an established release and quality standard, consequently assisting in food safety, the identification process, and future handling in the preparation of oils and medicine.

The main bottleneck identified was the creation of large databases for training solutions related to agriculture, with quality and diverse images, which serve not only an augmented reality but also solutions based on Artificial Intelligence and neural networks for tasks insights that may be developed in the future.

Many challenges still need to be overcome, but research continues and seeks to offer new versions and technological solutions to the market.

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