PillCrop: the Solution for the Correct Administration of Medicine

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Abstract: The present work brings to the reader's attention the benefits and facilities of the PillCrop application. The application enwraps a complete solution for improving the weight accuracy of each dose of medicine given to patients. The application recognizes, using artificial intelligence, the dose recommended by the medical specialist and the standard weight of each pill. If the medicinal drug can be divided it generates two surfaces that represent the necessary division of the pill to fit the weight indicated by the dose. This recommendation uses augmented reality to illustrate the part of the medicine that represents the recommended dose to the patient and where the pill should be divided.

Keywords: medicine, dose, patient, augmented reality, artificial intelligence.

1. INTRODUCTION

National healthcare systems have come a long way in terms of support from national governments (Ortiz-Ospina and Roser, 2021). With the help of these funds, remarkable discoveries have been possible internationally. These discoveries supported the increase of life expectancy from about 29 years in 1800 to 71 years in 2015 (Roser, Ortiz-Ospina, and Ritchie, 2021), which represents an increase of over 2.44 times.

The representation of the evolution of the funds of the national health systems as a ratio from the GDP is found in Figure 1 (Ortiz-Ospina and Roser, 2021). The increase in life expectancy at the international level from 1800 to 2015 is found in Figure 2 (Roser, Ortiz-Ospina and Ritchie, 2021). These results were also possible due to the increased number of medical staff internationally. Figure 3 represents the evolution of the number of doctors in the world since 1990 (World Health Organization, 2021).

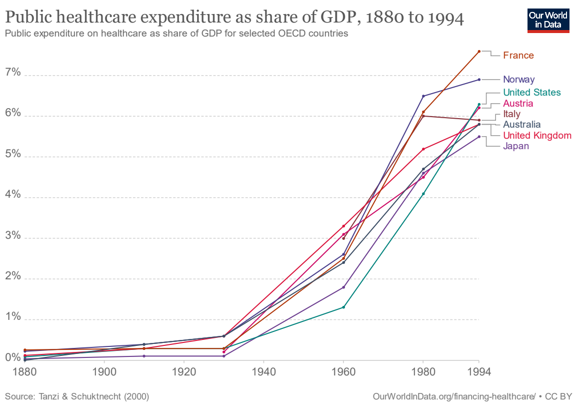

Figure 1. Public healthcare expenditure as a share of GDP.

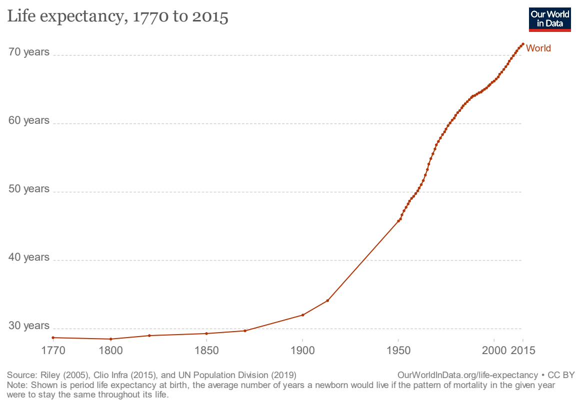

Figure 2. Life expectancy evolution.

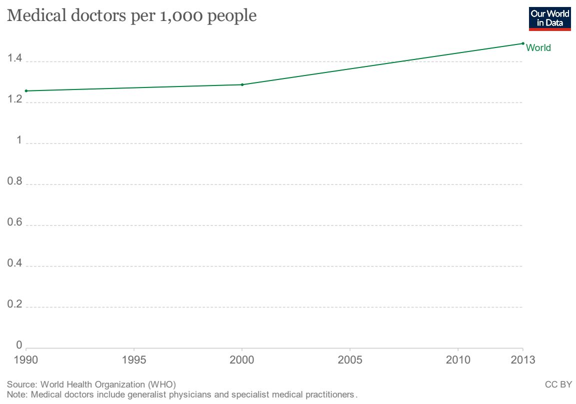

Figure 3. Medical doctors per 1000 people.

1.1 The importance of the application

Following the above, to maintain the trend of increasing life expectancy, innovative medicinal drugs have been developed that treat various diseases of the human body. Consequently, the value of 727.61 million people over 65 years of age was reached in 2020 (Our World in Data (a), 2021). The increase in the number of elderly people has been sustained since 1950 and is shown in Figure 4 (Our World in Data (a), 2021).

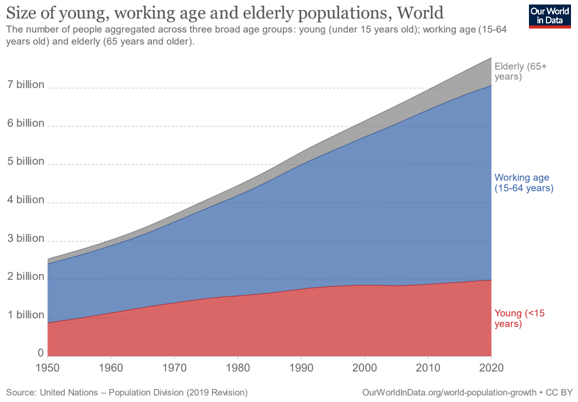

Figure 4. The evolution of the elderly population.

In addition, this growing trend of the elderly population is projected to continue in the future. The forecast of the evolution of the global population at the international level until the year 2100 is presented in Figure 5 (Our World in Data (b), 2021).

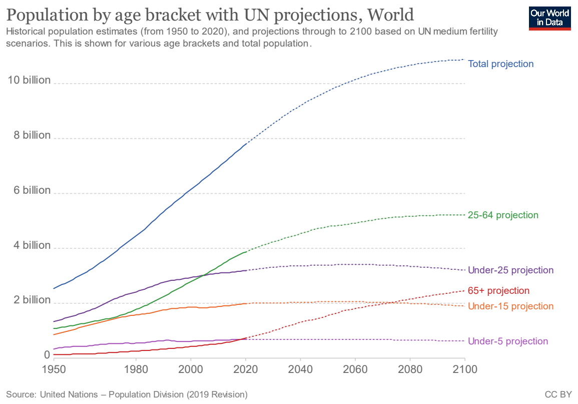

Figure 5. Projection of the population evolution until 2100.

Therefore, it is necessary to administer the medicinal drugs in the doses recommended by the medical specialists, this field being more and more important and of interest for the ever-growing category of people with medical problems. Unfortunately, drugs produced by pharmaceutical chains internationally are made in certain standard weights, and the doses prescribed to patients are individualized according to each person. This problem affects the effectiveness of treatment and must be resolved.

1.2 State of the art

Given the problem identified in the previous section, pharmaceutical companies have drawn lines on some pills to divide them into two halves, thus increasing the effectiveness of the medicinal drug administered to the patient. Medication companies have inserted lines on specific pills to divide the surface into two pieces. An eloquent example is Paracetamol, shown in Figure 6.

Figure 6. Paracetamol 500 mg pill.

In order to streamline the process of administering the recommended doses to patients, this paper will bring to the reader's attention the facilities provided by the PillCrop application. The application mentioned above allows the user to enter the current weight of the pill after taking a picture of the medicine box. Also, with the help of a picture, the value indicated as the recommended dose for the patient can be entered. All these facilities are achieved through text recognition using an optical character recognition algorithm. More details about the algorithm used will be presented in the following sections.

Given that not all medicinal drugs can be divided (Gracia-Vásquez et al., 2017), the application uses the Hough transform to identify the pills that can be divided.

Once the weight of the dose recommended by the doctor is known, the application uses augmented reality to overlap two surfaces over the pill: a dark one that represents the part of the pill that the patient must receive, and a transparent one to correctly identify the place through which the pill must be divided. Using Kanade-Lucas-Tomasi feature-tracking algorithm (Yongyong, Xinhua, Yujie, and Zongling, 2020), the application manages to keep the representation of the two surfaces even if the user changes the position of the pill.

Even though neural networks have been used for image detection and there are various applications in the field of augmented reality, for the best of our knowledge, there are no other applications that meet the goal of PillCrop: the correct division of pills with augmented reality to increase treatment effectiveness by reducing the area of the pill that can be given to the patient as the recommended dose. From a division into two halves, made by following the line imposed by the manufacturer, the application allows the division of the pill into an unlimited number of possibilities.

1.3 The structure of the paper

This paper is structured in 4 sections. In the introductory part, the reader finds information about the importance of the subject and the novelties of the paper. The second section contains an analysis of the literature in the corresponding medical and pharmaceutical fields, with an important emphasis on artificial intelligence and augmented reality. In the third section are presented the functionalities of the

PillCrop application, based on the state of art from section 2 and the options illustrated in section 1. The paper ends with a conclusion in which a summary is made regarding the performed work and the results obtained. In addition, the same section specifies the future development directions that the authors want to follow.

2. THEORETICAL BACKGROUND

2.1 Detection of the recommended dose and weight of the pill

Detection of numbers in images is a widely discussed topic in the literature, several data sets facilitate the development of detection algorithms based on neural networks: MNIST, NIST SD19 or USPS are among the most representative options (Kusetogullari, Yavariabdi, Hall, and Lavesson, 2021). MNIST contains 60,000 images that developers can use to train detection algorithms and another 10,000 images can be accessed to test the performance of developed algorithms. Compared to MNIST, the USPS database contains only 9298 samples, representing automatic captures of envelopes delivered by the U.S. Postal Service. NIST Special Database 19 is the richest in terms of stored images, with over 800,000 character images taken from over 3,600 writers (Grother, 2016).

With the help of these data sets, in the specialized literature, convolutional neural networks were involved. The results obtained after model training and testing were very satisfactory: the degree of correct classification varies between 95% for using a pattern recognition algorithm developed using PRTool (Prashanth, Mehta and Sharma, 2020) and 99.45% using a backpropagation algorithm (Kaziha and Bonny, 2019).

Given the increased number of images required to train neural networks and the time required for this operation, in the new application, the authors decided to implement an optical character recognition algorithm (Dalal, Daiya, 2018) to properly identify the weight of the pharmaceutical drug and the recommended dose by recognizing numbers in images. In this sense, the MATLAB ocr function (Mathworks.com (a), 2021) was used. From the tests performed by the authors, having at their disposal the Logitech C920 webcam, the detection accuracy is 30% following a set of 20 tests performed. It was thus necessary to validate the result by the user, through a personalized notification!

2.2 Detection of pills that can be divided

Regarding the recognition of pills, deep convolutional networks and convolutional networks are used in the literature. Also, the detection procedure varies depending on the specifications and performance of the algorithms: from a set of hundreds of images (Ou, Tsai, Zhou, and Wang, 2020) to just one image (Wang et al., 2017).

Consequently, the degree of validity of the generated results is strongly influenced: in the case of using a single image, it is between 11-46%, and for 5284 images, percentages of over 98% were obtained (Wong et al., 2017).

Starting from the observations in section 2.1, in the case of this paper, it was decided to approach a faster solution that does not require large sets of images to train and generates the same results. Starting from the observation that any pill that has a line imposed by the manufacturer can be divided by the patient, the PillCrop application detects the presence of the line on the surface of the pill. The Hough transformation (Mathworks.com (b), 2021) is used to identify the line after the initial image, shown in Figure 7, is converted to binary and the noise is filtered.

Figure 7. Example of an image used for line detection.

The result is shown in Figure 8. If the algorithm identifies at least 4 line segments in the processed image, it is considered that the pill can be divided. After performing 20 tests, the detection performance is 80%.

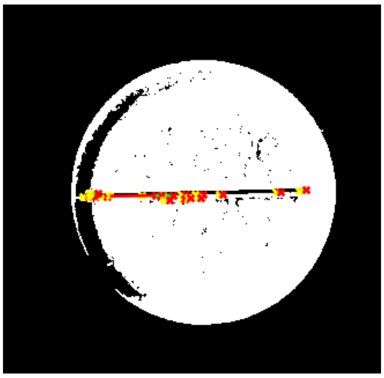

Figure 8. The result for line detection on the pill surface.

The application, following this procedure, checks if the user's desire is correct and meets the manufacturer's specifications, or wants to divide a pill that should not be divided (Gracia-Vásquez et al., 2017).

2.3 Augmented reality in medicine

The last step, according to the specifications in section 1, that the PillCrop application must meet is to use augmented reality to generate the two surfaces over the pill.

In this sense, the capabilities of augmented reality in the field of medicine and population safety were analyzed. Augmented reality applications have been identified in areas such as road safety (Tong, 2018) or psychological monitoring of patients while users were actively involved in exergames (Wiederhold et al., 2019). In the case of (Tong, 2018), a newly developed algorithm was used to determine the attention that pedestrians pay to the environment, based on parameters such as heart rate or mobile phone use. If the user of the application did not pay attention to what is happening around him and the application detects an imminent danger, the pedestrian is warned through a graphical interface that uses augmented reality. Wiederhold et al. used the augmented reality game mode to increase people's mobility and reduce stress levels. Moreover, augmented reality is successfully used in oral surgery (Peters, Linte, Yaniv, and Williams, 2019).

Therefore, an application that uses augmented reality in the pharmaceutical field will easily integrate with other applications already developed in order to protect people's health. Also, the number of users of the application will be constantly growing given the increase in life expectancy.

3. PILLCROP APPLICATION

3.1 Data retrieval

The first step in using the application is to capture the reference image and check the ability of the pill to be divided. If the Hough transformation does not identify the presence of the line, an error message like the one in Figure 9 is generated.

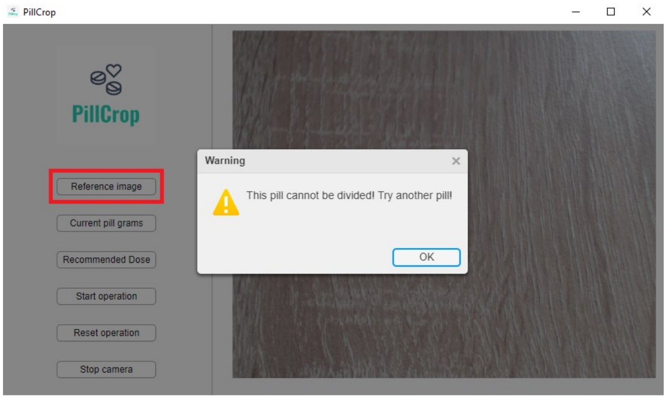

Figure 9. Error message due to non-identification of the pill line.

The next step is to use the weight detection algorithm. Regarding the identification of the standard weight of the pill, the graphical interface of the application is the one in Figure 10.

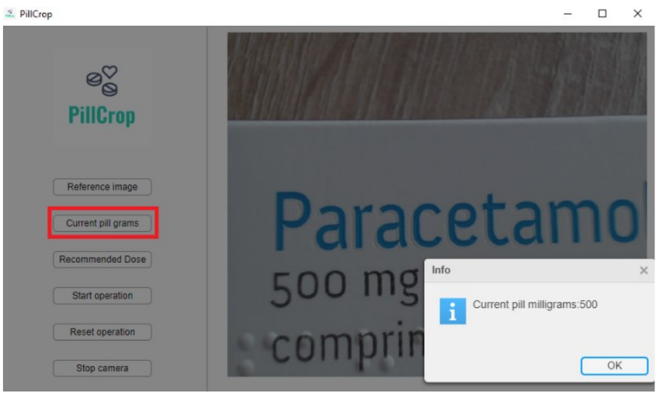

Figure 10. Identification of the standard weight of the pill.

To identify the dose recommended by the medical specialist, the "Recommended Dose" button in the graphical interface is pressed, and the obtained result is presented in Figure 11.

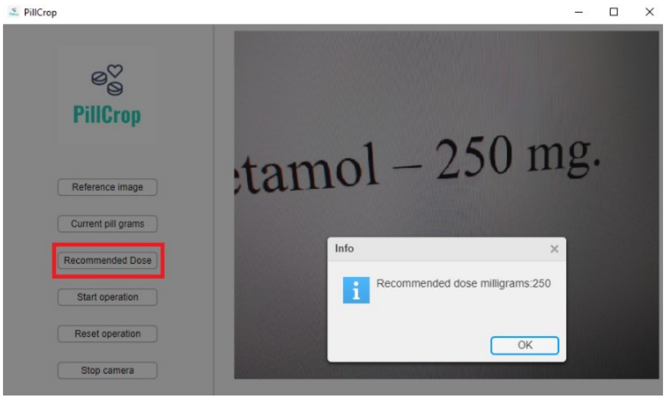

Figure 11. Identification of the dose weight.

In order to achieve the correct reading, the user must capture with the help of the webcam only a single number to be later used as a reference for the variable in question. For this reason, to ensure the correct recognition of weights, the user is informed about the read values. If it identifies an error, it can restart the process by pressing the "Reset operation" button.

To improve the performance of Wang et al. regarding the extraction of the particularities from the initial image for training a colorful background was used, and the image quality was tried to be as good as possible. The background of the image is represented by an area of 2x2 centimeters, divided into four rectangles of two lines that intersect in the center of the surface. Therefore, the user is encouraged to place the pill in the center of the surface, to increase the probability of correct detection of features.

If the analyzed image is blurred and does not allow the exact identification of the features of the pill, a new error message is generated according to Figure 12.

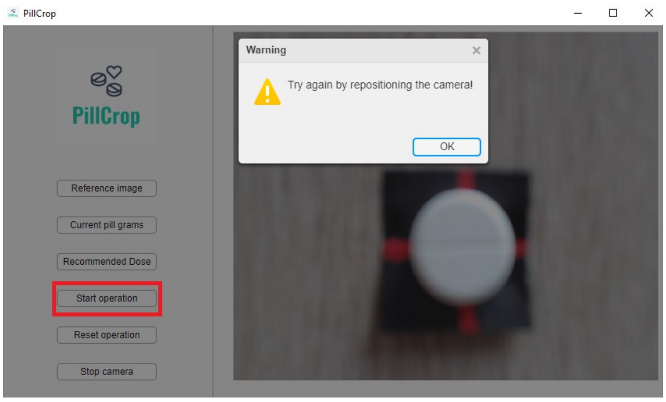

Figure 12. Pill identification error.

3.2 Results generation

To generate the results the first step is to calculate the ratio between the recommended dose and the standard weight of the drug. For this purpose, the data registered in the steps presented in the previous subsection are used. Based on the previously determined ratio, the percentage between the two surfaces is calculated: the one that represents the dose that must be administered to the patient and the one that must be stored for a later administration. Depending on the calculated percentage, the two surfaces must be generated. To achieve this goal, a diagonal matrix for determining the surfaces was used, in which the previously defined percentage between the two surfaces was considered.

Therefore, the division of the pill into two parts can be achieved in an infinite number of cases, depending on the particularities of each medicine administered to the patient. A black image will be superimposed over the surface that represents the part of the pill to be administered to the patient, and the other part will remain transparent.

If the pill can be divided, after pressing the "Reference image" button, the initial image is shown in Figure 13. The last step that the user must take is to press the "Start operation" button.

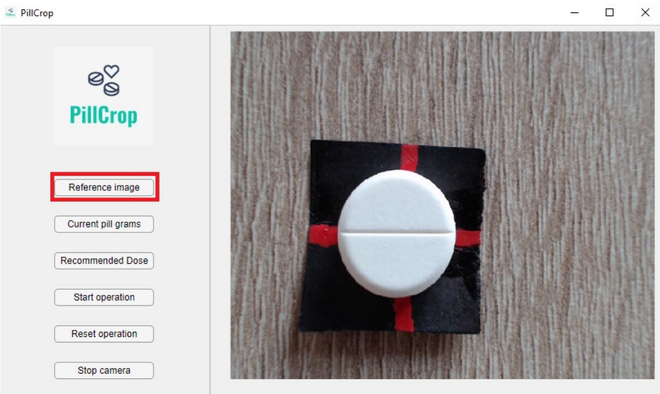

Figure 13. Initial pill capture.

The algorithm developed by the authors takes the initial screenshot of the pill, shown in Figure 13, and determines if the pill is identical to the one used in the first stage of training the application. To consider the two pills identical, it is necessary to correctly identify at least 2 common features, via the matchFeatures function in MATLAB (Mathworks.com (c), 2021). If this identification is not possible, the user is warned by a notification message of the result of the application, and it is recommended to change the viewing angle of the pill. The information message is similar to the one shown in Figure 12. To ensure the necessary privacy, the user can disconnect the camera by pressing the "Stop camera" button.

The authors of this paper performed a series of tests to verify various cases of use of the application. These cases are not similar to the recommendations for using the application, but they may occur in the current use of the application if the user misuses the application. The results of the tests performed by the authors indicated that the algorithm is able to correctly generate the two surfaces even if the pill is not in the center of the surface of 2x2 centimeters or if the shape of the pill is not round. The same positive result is obtained if the dividing line of the pill is positioned in a different direction than the one used for training. All these results were obtained exclusively if the edges of the background surface of 2x2 centimeters could be detected, leading to its decisive importance. Thus, cases such as exceeding the surface due to the size of the pill, replacing the pill after the training stage, or positioning the pill outside the surface led to erroneous results, not being possible to generate the two surfaces.

If the two pills are identical, the application generates the final result by overlapping the two surfaces over the initially identified pill. The final result is shown in Figure 14. Given that the users of the application will generally be elderly people who have mobility problems, the PillCrop application allows tracking the pill using the Kanade-Lucas-Tomasi algorithm (Yongyong, Xinhua, Yujie, and Zongling, 2020) and generating a new surface. This facility was included taking into account people suffering from diseases with results similar to those caused by Parkinson's disease.

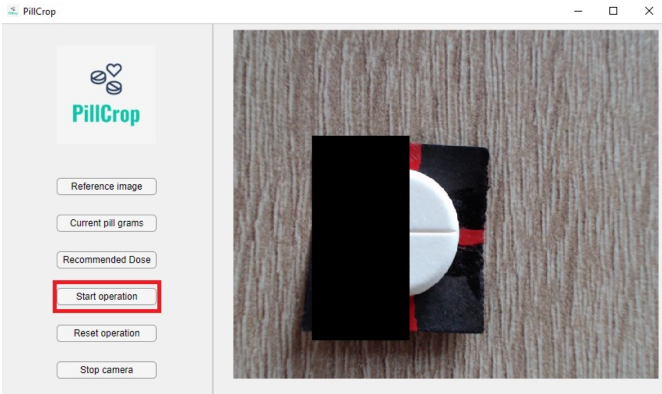

Figure 14. The result obtained after using the PillCrop app.

4. CONCLUSIONS

In this paper, a segmentation application was developed using artificial intelligence and augmented reality. An optical character recognition algorithm was used to detect the weight of the pill and the recommended dose to the patient. To detect whether the pill can be divided or not, Hough transformation facilities have been used. Moreover, the authors developed an algorithm that determines the area of the analyzed pill that represents the dose recommended by the medical specialist. Moreover, by using a 2x2 centimeters background surface in contrasting colors, the authors were able to obtain remarkable results for the pill detection algorithm using a single image for training. In addition, the developed algorithm allows real-time tracking of the pill and encourages the user to divide the pill by a recommended area that is much closer to the dose indicated by the medical specialist.

Compared to the division recommended by the manufacturer, in two halves, the PillCrop application allows the division of the pill into an infinite number of pieces.

In order to avoid the decisive influence of the training process of the neural networks, in this paper were used mathematical algorithms that were less affected by the training process. Some examples of this are the Hough transformation for identifying pills that can be divided, an optical character recognition algorithm for recognizing numbers, or the Kanade-Lucas-Tomasi object tracking algorithm.

In terms of further development directions, the authors aim to develop a native mobile application to facilitate the use of the PillCrop application originally developed for computers. Also, the integration of the application results in a specialized device for cutting pills is of interest to authors.

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