# DeskEmo, a multi-platform desktop software for remote control and monitoring of hematological parameters

Vita Santa Barletta[1][0000-0002-0163-6786], Mauro Giuseppe Camporeale[1][0000-0002-0323-5505], Nunzia Lomonte[1][0009-0000-5009-6424], Michele Scalera[1][0000-0002-2455-2032], Enrichetta Gentile[1][0000-0002-4502-030X]

[1] Dipartimento di Informatica, Università degli Studi di Bari, Bari, 70121, ITALIA
mauro.camporeale@uniba.it

**Abstract.** Anemia is a pathology that affects approximately 25% of the world population. In recent years, research is focusing on developing cheap, precise and non-invasive tools to detect anemia from different regions of the body. Many works obtain good performances in estimating the anemic status of patients but very few focus on allowing them to be screened at home while giving them the opportunity to be continuously monitored by physicians. In this work we present DeskEmo, a desktop application developed to enable doctors and laboratory physicians to remotely monitor patients' hematological parameters extracted by a mobile application called Hbmeter.
The technologies illustrated here will be tested with the collaboration of the Giovanni Paolo II hospital in Bari, Italy in the coming weeks.

**Keywords:** Telemedicine, Anemia-detection, Non-invasive, Web technologies.

## 1 Introduction

According to publications by the World Health Organization, anemia emerges as a pervasive global health concern, impacting approximately 25% of the populace with varying levels of severity [1], [2]. Iron deficiency, infectious diseases, and genetic factors emerge as the primary determinant causes of anemia. In scientific literature, anemia is characterized by a decline in red blood cells and hemoglobin (Hb) concentration levels, resulting in impaired oxygen transportation to the peripheral tissues and diminished blood functionality.

Maintaining continuous monitoring of severe anemia is essential since severe forms of anemia can induce a substantial decrease in oxygen availability to the cells, leading to detrimental effects on vital organs. When dealing with instances of severe anemia, hemoglobin (Hb) levels are assessed frequently through laboratory analysis of a blood sample; continuous monitoring is necessary because it is not uncommon to have to perform blood transfusions to raise very low Hb levels.

This pathology is subtle because it evolves slowly and does not present easily recognizable symptoms. When the compensatory mechanisms initiated by the human body fail to adequately ensure the appropriate quantity of oxygen circulating throughout the system, distinct symptoms manifest unequivocally. The symptomatology varies in accordance with the severity and specific type of anemia; however, common characteristic symptoms encompass pallor, asthenia, tachycardia, syncope, decreased appetite, nausea, and exertional dyspnea [3]–[5].

Anemia detection techniques can be subdivided into invasive and non-invasive. Invasive techniques necessitate the collection of blood samples, which can lead to patient discomfort, carry the risk of infection, and require subsequent laboratory analysis. Non-invasive techniques prove crucial for individuals who frequently undergo blood tests or experience blood loss [6]. These techniques often rely on assessing the pallor of specific body parts as an indicator of anemia presence or absence [7]–[10]. These techniques hold significant importance for patients who require frequent blood sampling or face challenges in mobility, particularly those who cannot readily leave their homes. Moreover, in line with the current healthcare trend, there is a growing emphasis on treating patients in the comfort of their own homes whenever feasible, facilitated by innovative therapeutic care pathways and services, such as electronic medical records [11], [12].

In recent years, significant strides have been made to enhance the precision of non-invasive tools [13]–[15]. These devices can be developed to be portable, affordable, and user-friendly, providing considerable benefits in terms of rapidity in obtaining a pre-diagnosis and in self-monitoring. The affordability of these devices could enable widespread screening, even in economically disadvantaged regions with limited resources.

Similar to other medical fields that leverage image analysis, sound or signal analysis, and artificial intelligence techniques [16]–[20] it is imperative to foster research and development of innovative technologies for addressing anemia. By doing so, there are numerous advantages to be gained, including cost reduction for national health systems and fortifying medical and healthcare services.

Many studies are being made to design a non-invasive system to allow a patient to self-monitor their anemic status. In [21] is developed an IoT device that detects the redness of the blood and send it to a central server to be processed along with a questionnaire the patient has to compile. A mobile app is proposed in [22] where pictures from the fingertip and a patient questionnaire are analyzed from a machine learning algorithm and then sent back to the smartphone mobile app. [23]–[25] all provide non-invasive systems to detect anemia using a smartphone to analyze different regions of the body.

All this systems allow the patient to be screened in a non-invasive way by going to the place where the screening takes place; if the patient wants to be screened at home the doctor has to go to the patient’s house or the patient has to interpret the screening results by himself.

That is why we propose DeskEmo, a desktop application developed to enable doctors and laboratory physicians to remotely monitor patients' hematological parameters. DeskEmo prioritizes simplicity, differently from other applications with complex configurations, unintuitive interface, and incompatibility with hardware and software available in the doctor's office or laboratory. It requires no special installation procedures and has a user-friendly interface that mirrors the design of its mobile app with which it interacts [26].

## 2 Hbmeter

This project is based on the system designed and developed in the research [26], called Hbmeter. This is a software developed for the iOS platform and for devices equipped with the Android operating system. It uses a non-invasive method for estimating Hb levels by analyzing images of a specific region of the conjunctiva. This system will be used by patients at home to decide if they should contact a physician, and to track their value of Hb.

A device was designed and constructed in the research to enable patients to capture precise images using their smartphones. The device features LED lights, specialized macro-lenses, and a rubber ring that can be easily positioned around the eye area to be photographed.

The app involves an initial phase of image acquisition or selection of a photo taken previously. Subsequently, the user must select an area that includes the conjunctiva and, thanks to the Simple Linear Iterative Clustering (SLIC) [27] algorithm for superpixel generation, the selected area is improved and made more precise. The third step involves the use of a k-nearest neighbors' algorithm to predict the level of anemia, which can be high-risk (Hb<10.5 g/dl), doubtful (10.5 < Hb < 11.5), and low-risk (Hb > 11.5). This prediction shows a strong correlation between actual Hb levels obtained through blood sampling and those estimated. During the analysis phase, the app stores relevant data to display in a dedicated section. The user can view information of interest for each of the previous analyses performed. More specifically, this information includes: the image of the selection made, the date and time of the analysis, and the average value of the a* channel. This feature allows to keep a history of analyses performed and review them whenever desired. These reports are the components used by DeskEmo that will show them to the doctor alongside the pictures collected from HBmeter.

## 3 Technologies and tools used

DeskEmo was developed using Electron, an open-source framework that enables the creation of desktop applications using web technologies such as JavaScript, HTML, and CSS. As a result, DeskEmo's user interface and functionality are entirely based on these technologies. One of the key benefits of using web technologies to develop a desktop application is portability. DeskEmo can be seamlessly run on a variety of popular operating systems.

DeskEmo receives information from Hbmeter through secure channels that ensure authentication, data integrity, and encryption. This is achieved by utilizing the IMAP protocol for transmitting emails over the internet. All sensitive information exchanged via email is stored locally on the doctor's device for the time necessary for the doctor or specialist to verify the patient's status and health. After this time, the information is permanently deleted to ensure an additional level of security and privacy for each individual patient. Historical data is stored without references to personal data to guarantee privacy and security. The connection with the original patient is maintained using an encrypted key that is periodically sent by the patient's Hbmeter application.

## 4 DeskEmo description

DeskEmo was designed to be an out-of-the-box software that does not require any installation or special configuration. This allows doctors to operate independently without the need for expert intervention.

The DeskEmo interface has been designed to mirror the graphic style of the Hbmeter smartphone application, providing a familiar user experience. The interface is responsive and can adapt to any screen size for optimal viewing. The DeskEmo interface is organized into three main sections for ease of use:

1. ***Report:*** all analyses submitted by patients to their doctor are displayed in this section. These are organized in a data-table for quick and effective searching based on key fields in the header-line (Fig. 1). The tabular layout allows the doctor to quickly view essential information such as the patient's name, email address of the sender, and date of analysis. Each analysis is labeled to indicate whether it has been viewed by the doctor. By clicking the 'View' button, the doctor can access detailed information about the selected analysis, including the patient's personal data, the average value of the a* channel calculated by Hb Meter, digital image acquired by the patient, and selection of the conjunctival eyelid made on the previously captured image (Fig. 2).

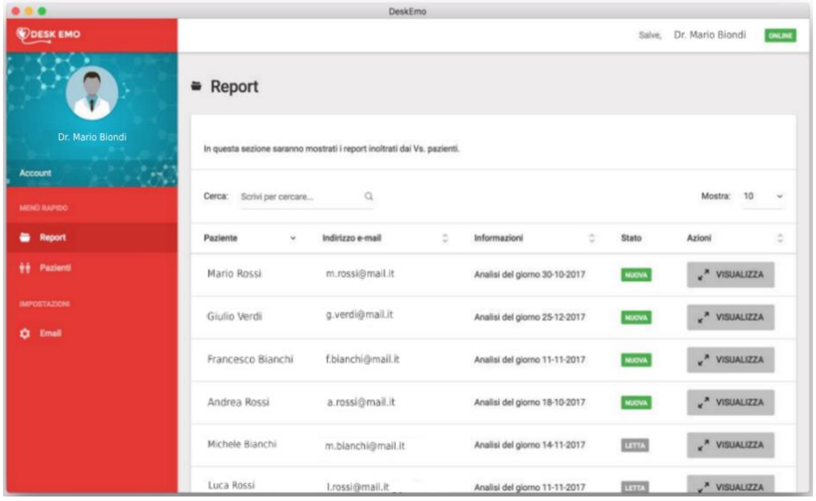


**Fig. 1.** Reports list section.

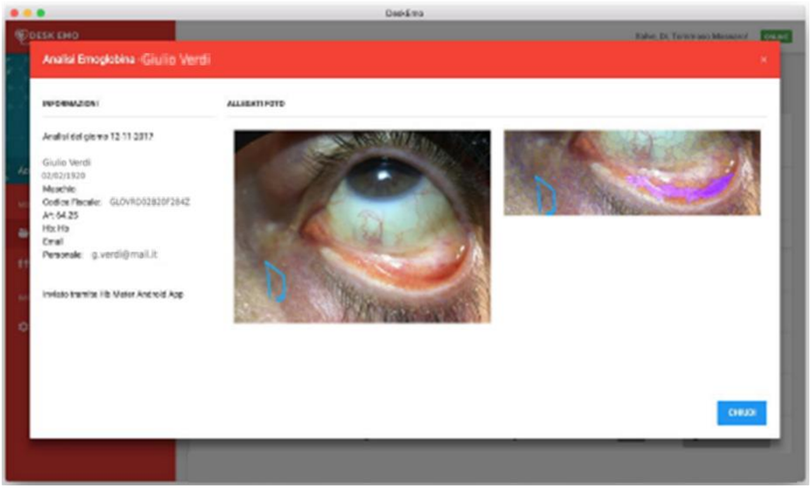


**Fig. 2.** Visualization of a single report.

2. ***Patients:*** it is the section dedicated to managing the personal data of individual patients. Like the Report section, all information is organized in a datatable. The tabular layout allows the doctor to view a range of personal information for each patient, including their name, date of birth, tax code, and email address (Fig. 3). Each patient is uniquely identified by their email address. By clicking the 'View' button, the doctor can access detailed information about the selected patient. In addition to their personal data, a graph will be displayed that tracks the patient's health conditions over time (Fig. 4). This graph is generated using average values of the a* channel from each analysis submitted by the patient, along with their corresponding dates. Ad-

ditionally, by simply hovering the cursor over any point on the graph, it is possible to view the exact value of a* for an analysis performed on a specific date (Fig. 4).

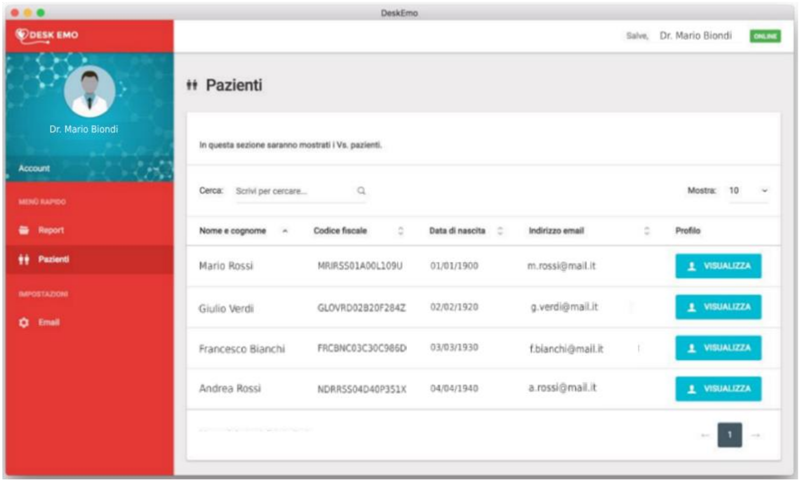


**Fig. 3.** Patients list section.


**Fig. 4.** Visualization of a patient’s health condition over time.

3. ***Email***: this section allows you to view and edit information related to your email account used by DeskEmo (Fig. 5). DeskEmo includes a log-out feature that allows you to delete the login credentials for the current account and clear the archive of personal data and analyses created by the system. After logging out, the application restarts and displays the initial configuration screen.

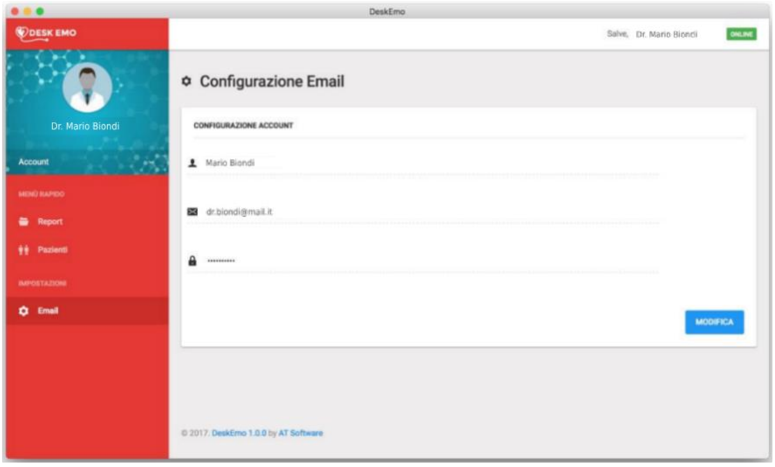


**Fig. 5.** Email section.

The interface has been designed in a modular way, so that each component is independent from the others, this has been done to guarantee easy updates in future versions of the application but also to allow to develop new features without concerns about creating errors in currently implemented components.

## 5 Conclusion

Currently research about new techniques and devices for non-invasive anemia detection is flourishing, but very few of this research cares about giving the patient the possibility to be tested at home and at the same time the safety of being monitored by a physician. In this study we propose DeskEmo as complementary component of Hbmeter [26], to enable doctors and laboratory physicians to remotely monitor patients' hematological parameters extracted from the mobile application on the patient smartphone.

DeskEmo prioritizes simplicity, it requires no special installation procedures and has a user-friendly interface that mirrors the design of its mobile app with which it interacts.

In a doctor's office, where time and efficiency are crucial for carrying out diagnoses, DeskEmo excels by distinguishing various reports from ordinary mail, tracking the history of various hematological parameters, and organizing all data efficiently and effectively for easy and immediate consultation. The enormous potential of web technologies makes DeskEmo a flexible software capable of continuously integrating new functions.

Some ideas for future developments include designing a multi-account system to use multiple email addresses for receiving reports; integrating DeskEmo with the Personal Electronic Health Register creating new mobile applications that can communicate with DeskEmo and forward non-hematological parameters; and implementing a more secure authentication and communication method for the mail client using REST architecture and APIs provided by major email providers.

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