Design and implementation of a high productivity user interface for a digital dermatoscope

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TESI DI LAUREA

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Abstract

Information technology offers great potential for healthcare applications. Modern medicine is increasingly taking advantage of digital imaging and computer-assisted diagnosis. Dermatology is no different. Digital dermatoscopy is emerging as the standard for diagnosis of cutaneous lesions. High quality digital images allow dermatologists to improve accuracy, and to assess the evolution of lesions. However, state-of-the-art technology fails to support dermatologists in daily practice: the available systems on the market increase average visit time, and are expensive. Thus traditional methods, albeit inferior, are often preferred.

To overcome such limitations the Department of Information Engineering, University of Padova, in collaboration with the Dermatology Unit, School of Medicine, started the Cutis in Silico project. Cutis in Silico (CiS) promises a time-cost effective solution for melanocytic lesion evaluation. The project is divided in three components: the mole mapper, a digital dermatoscope and visit support tool, the body scanner, an appliance for acquiring and analyzing full-body images of lesions, and the personal screener, a low-cost, portable instrument allowing patients to acquire "at home" dermatoscopic images of lesions. For the scope of the project, a factor that affects time efficiency more than computational power is human-computer interaction. This thesis focuses on the design of an user interface for the mole mapper, the core component of the platform.

Enabling a highly efficient use of the digital dermatoscope will shorten average visit time, and thus allow screening a higher portion of the population at risk with higher frequency. The efficiency of interaction is achieved applying a goal-directed design methodology, based on the analysis of the user mental model. Personas are user models that capture aspects of their behaviors, motivations, attitudes and aptitudes. Through the use of personas it is possible to focus the design on the actual needs of users, thus eliminating functional excise, and optimizing interaction. In addition, the software architecture for the interface is defined and contextualized in the broader vision of the project. To let the mole mapper work in synergy with the other components of the system, Android is chosen as the development platform.

While, due to delays in the development process, we could not obtain quantitative results, several metrics and user testing methodologies are discussed to evaluate the efficacy of the design.

Contents

Introduction

Healthcare systems are on the verge of confronting an utmost challenging phase in their history. The demographic shift towards age-average growth is boosting the demand for medical support [54]. The capacity of public and private healthcare facilities in the so-called developed world is next to be exceeded. Legislations struggle to keep the pace of the emerging necessities, and do not provide effective countermeasures to abate the disparity between the right to assistance and the actual population coverage.

Skin cancer is the most common form of human cancer; it has been estimated that nearly half of all Americans who live to age 65 will develop skin cancer at least once [16]. While a less common variant (5% of all skin cancer cases), melanoma causes the majority (75%) of the related deaths [30]. In the past few decades, the incidence of cutaneous melanoma has increased more rapidly than for any other cancer [28].

Periodic screening and timely diagnosis result with high probability in positive prognosis for melanoma cases. The survival rate is very high if melanoma is detected in its early stages, when it can easily be removed surgically. However, aggressive forms of melanoma can become deathly within three months from their first appearance [26]. Public infrastructures therefore encounter difficulties in screening the population at risk at sufficiently high frequencies.

Dermatoscopy is a non-invasive technique that allows inspection structural features of skin lesions that would otherwise be indiscernible, using a specialized handheld optical device called a dermatoscope. Studies prove that dermatoscopy significantly improves diagnostic accuracy for skin cancer, and for other skin diseases, in respect to both sensitivity and specificity [27]. Anyhow, traditional dermatoscopy is a time demanding practice, and requires specialist training. Diagnosis is based on non-reproducible, qualitative assessments that tend to depend on the experience of the dermatologist. Moreover, current practices often fail to address the issue of lesion evolution in time; whereas evolution is probably the most important metric in the assessment of melanoma (and many other pathologies).

These shortcomings have been, at least partially, addressed by the introduction of digital dermatoscopy systems. Digital dermatoscopes provide ways to compare sets of reference digital photographs of lesions in time, while typically extending the delivered support to computer-aided diagnosis and, more recently, teledermatology [20]. It has been attested that diagnostic accuracy for melanoma is further increased by digital dermatoscopy [51].

Nevertheless, current state-of-the-art digital dermatoscopy systems do not make visit routines faster - in fact, they tend to slow them down. In addition, current computerized systems do not match real life practices in lesion evaluation, which often follow unwritten rules. The causes for such deficiencies are the cumbersome physical form factor of the systems, often embedded in dedicated tray tables and racks, and insufficient attention to usability.

Cutis in Silico, abbreviated CiS, is a project developed at the Department of Information Engineering, University of Padova, in collaboration with the Dermatology Unit, School of Medicine. The project goal is the development of automated and computer-assisted systems for the evaluation of cutaneous lesions - and in particular melanocytic lesions - that will reduce the time-costs for dermatologists and increase diagnostic accuracy. This document presents the design and development of the user interface for the core component of the CiS system, the digital dermatoscope, which is the functional hub for the service framework. The main objective of the interface is that of empowering dermatologists to be highly efficient. An adaptation of the Goal-directed methodology is used to investigate the users' mental model and analyze their vision of the tasks that precede diagnosis. A novel streamlined workflow is then distilled after uncovering non-explicit domain knowledge. This forms the basis for the development of the graphical user interface for a tablet PC platform – which proved to be best choice in terms of interaction flow and ergonomy.

The time savings effected through our system will hopefully allow a wider portion of the population at risk to receive proper screening, elevating the probabilities of survival from skin tumor.

The rest of the thesis is organized as follows. The first chapter provides an overview of the domain-specific problems of technology applied to dermatoscopy. The second chapter presents the structure of the Cutis in Silico project. The third chapter summarizes the results of user research, and describes the derived models for users and functional requirements. The fourth chapter motivates the choices behind the interaction framework, while the fifth details the visual rendering for the interface. The sixth chapter discusses procedures for validating the design. The seventh defines the structure for software development. The last chapter summarizes our results and examines their implications before briefly sketching some directions for future research.

Chapter 1

Digital dermatoscopy

In order to comprehend the motivations that inspired the development of CiS, it is important to have a synopsis of dermatology-related domain knowledge. An overview of how melanoma evolves, and of symptoms on which diagnosis is based, is crucial in understanding why dermatoscopy is a key methodology for timely and accurate melanoma identification. Presenting the currently applied screening routine will then explain why obtaining higher efficiency is problematic with traditional methodologies. This will make readily apparent the potential advantages provided by digital technological support tools.

1.1 Melanoma

Dermatology is a specialization of medicine that requires the development of an unique set of skills. Even if dermatologists receive in-depth training along one of the most selective and extended in time study courses, diagnosis is performed relying on a trained eye and years of experience as main tools. Melanoma investigation is one exemplary task that demonstrates the difficulties of attaining such competence and formalizing it in quantitative measures.

Melanoma (from Greek melas, "dark") is a malignant tumor that predominantly occurs in skin. It can develop from a pre-existing mole (*ex naevo*), or have an independent existence (*de novo*). 1 in 50 people is diagnosed with melanoma of the skin during his lifetime. In the past few decades, the incidence rate of cutaneous melanoma has increased more rapidly than for any other cancer [16]. According to a World Health Organization (WHO) report, about 48,000 melanoma related deaths occur worldwide per year [28].

Table 1.1: Survival figures for melanoma from the British Association of Dermatologist Guidelines 2002

Tumor Depth	Approximate 5 year survival
< 1 mm	95-100%
1 - 2 mm	80-96%
2.1 - 4 mm	60-75%
> 4 mm	50%

1.1.1 Evolution

Melanocytes are found between the outer layer of the skin (the epidermis) and the next layer (the dermis). Melanoma typically evolves in two phases, first expanding planarly, then invading vertically. In the first stage, the radial growth phase, the tumor is typically less than 1mm thick, not involving the whole epidermis in depth. As at this early stage cancer cells have not yet reached blood vessels, cancer is unlikely to spread to other parts of the body, and it can usually be completely surgically removed. In the second stage, the vertical growth phase (VGP), the tumour attains invasive potential, growing into the surrounding tissue and spreading around the body through blood or lymph vessels. The tumour is usually more than 1mm thick, and it involves the deeper parts of the dermis.

Early recognition of melanomas still characterized by modest depth, followed by integral excision, leads to high chances of survival. Once melanoma spreads internally, survival rate is 50%; this figure decreases rapidly as thickness further increases (1.1). The probability of recurrence or metastasis too is correlated with tumor penetration depth.

Monthly thickness growth rates are typically just above 0.1mm per month for superficial spreading melanoma (the most common form of cutaneous melanoma in caucasians) and around 0.5mm per month for nodular melanoma (a fast-growing, aggressive form of melanoma). Depth greater than 1mm often marks transition to the invasive phase of melanoma: radial melanoma can therefore reach an incurable stage in 6 to 18 months, while nodular melanoma in less than 3 months. For treatment to be effective, patients at risk should be screened more often than once per year.

1.1.2 Diagnosis

A very rough mnemonic guideline for melanoma diagnosis is the *ABCDE* rule:

A Asymmetrical Shape: Melanoma lesions are typically irregular, or not symmetrical, in shape. Benign moles are usually symmetrical.

B Border: Typically, non-cancerous moles have smooth, even borders. Melanoma lesions usually have irregular borders that are difficult to define.

C Colour: The presence of more than one colour (blue, black, brown, tan, etc.) or the uneven distribution of colour can sometimes be a warning sign of melanoma. Benign moles are usually a single shade of brown or tan.

D Diameter: Melanoma lesions are often greater than 6 millimeters in diameter - yet many melanomas present themselves as smaller lesions, and all melanomas are malignant on day 1 of growth.

E Evolution: Any change – in size, shape, colour, elevation, or another trait, or any new symptom such as bleeding, itching or crusting – points to danger.

The *ABCDE* rule cannot be applied to nodular melanoma, in which case the alternative *EFG* rule usually is used:

E Elevated: the lesion is raised above the surrounding skin.

F Firm: the nodule is solid to the touch.

G Growing: the nodule is increasing in size at a fast pace.

It is worth noting how all considered features are qualitatively described, and not easily measured. Not all signs need to be present for a melanoma diagnosis. More in general, all these rules should be applied critically. Dermatologist experience is indispensable. For example, an important criterion is the so called *"ugly duckling"* rule: lesions markedly different from the remaining ones on the patient are at much higher risk. Warning signs can be detected only if frequent screening is performed.

Tools for comparing different images of the same naevus in different points in time, or of different naevi in different body locations in the same patient are then fundamental for correct diagnosis, in that they allow assessment of both evolution and *"ugly duckling"* issues.

1.2 Dermatoscopy

Dermatoscopy, or epiluminescence microscopy, is a non-invasive technique that allows highlighting details of lesion structures that would otherwise pass unnoticed by the naked eye. It is performed by examining the skin surface making use of a specific optical device called dermatoscope. Although it is traditionally used for detecting melanomas, it can successfully be applied to aid diagnosis of other kinds of skin tumors - such as basal cell carcinomas, squamous cell carcinomas and dermatofibromas - as well as a wide range of other skin diseases. Expert usage of this tool leads to significantly higher levels of diagnostic accuracy.

A dermatoscope, as pictured in figure 1.1, is formed by a magnifier (typically providing a x10 zoom), an incident light source, a transparent plate and a liquid medium between the instrument and the skin. This setup permits inspection of subcutaneous features of skin lesions without the obstruction of skin surface reflections. More recent dermatoscopes make use of polarised light to remove skin surface reflections. Polarized dermatoscopes offer the advantages of not needing contact with the skin, thus dispensing with the use of a liquid medium. On the other hand, most of dermatoscopic images that have been published have been taken with traditional dermatoscopes, and images taken under regular epiluminescence show slightly different lesion qualities; such issues discourage in part the switch to the newer, more effective, technology. Studies prove that dermatoscopic inspection improves sensitivity (detection of melanomas) up to 20% and specificity (percentage of non-melanomas correctly diagnosed as benign) up to 10%, compared to naked eye examination [31, 51].

Figure 1.1: A popular compact dermatoscope. Source: *http://www.dermlite.com/*

While traditional dermatoscopy empowers dermatologists with a more detailed view of lesions, it fails at providing methods for image acquisition, comparison and storage; digital dermatoscopy is the answer to these needs. Many efforts are being spent also in the direction of automated diagnosis, and its fundamental research for a new semiology based on objective measures of atypical moles [42]. While it is true that acceptability of automated diagnosis is still low, the demand for an evolution of dermatoscope as a diagnosis support tool is ever rising.

1.3 Mole mapping

The iter a naevus must undergo before it is classified as malicious is fairly complex and spans several check-up visits. Moreover, in each visit the routine dermatologists perform is composed of multiple steps that are considered common practices, but that in fact are executed following different, often personal approaches. While dermatoscopy is consistently the crucial step for diagnosis, exploring the context of all other procedures involved in patient monitoring is essential for understanding its functional role.

Typical visits can be divided into first-time and follow-up visits. On first time visits, the so-called *mole mapping* is performed. Despite the name, mole mapping consists in making the patient undress, minutely cataloguing his naevi one by one. As patients can present hundreds of moles, the procedure is time consuming, and requests high degrees of memory and concentration. Fraction of lesions inspected, order of inspection, and techniques to “annotate” suspicious lesions are dictated by the single dermatologist’s experience. Afterwards, if digital tools are available, the physician takes full body photographs of the whole skin surface, for future reference. Illumination, zoom, camera distance, and even body subdivision into areas don’t present agreed-upon conventions. Handling of full body photographs taken by different doctors is often cause to debates. Naevi that are considered suspicious are then graphically annotated, often with pen markers, and medium range photographs of the area are taken, in order to be able to localize the naevus afterwards. Successively, suspicious naevi are controlled with a handheld dermatoscope and/or recorded on a digital medium through a digital dermatoscope. A final report is then formulated by the dermatologist, stating which lesions need to kept under surveillance in follow-up periods typically of 3, 6, 12 months, and which lesions must be surgically removed. The report might have photographs attached as reference for the surgeon to correctly locate the lesion.

On follow-up visits the steps involved are similar, with the notable addition of the need to confront, where available, historical reference of full-body and dermatoscopic images with the current condition of the patient, in order to determine the appearance of new moles, and the growth of moles under observation.

A necessary note is that often not all steps are performed completely due to time restrictions, and their order is a matter of individual preference. The whole procedure is highly non standard. Exact classification is possible only after (and if) a lesion is excised, making a histopathologic analysis possible. It is important to note that, since skin surgery in the great majority of occasions doesn't have long-term effects, dermatologists often err on the side of caution.

1.4 Digital dermatoscopy: State of the Art

Optical dermatoscopy improves diagnostic accuracy for melanoma, and it can also be applied to a wide range of other skin diseases. The analog dermatoscope is a simple, useful tool; still its effectiveness is limited by factors determined by its intrinsic physical structure. Digital dermatoscopy intends to overcome such limitations.

1.4.1 Benefits

Digital dermatoscopes offer several advantages over traditional ones. Perhaps the most important advantage of digital dermatoscopy is the ability to store digital images. The evolutionary nature of many skin diseases could only be captured in traditional practice by interviewing the patient (who often has a distorted view of symptoms), or by visual clues, which are less obvious in early stages, which are less obvious in early stages when the diagnosis is of greatest use. It should also be noted that a digital dermatoscope can easily transform into a normal digital camera by removing the optical group and illumination source. This allows one to use the same system for taking full-body images useful to "map" individual lesions on the patient's body. Digital images can easily be manipulated to allow one-on-one and step-by-step comparisons of different moles, or of the same mole in different points in time. Moreover, a overview of all moles captured can be summarized with little to no effort. Until recent years such comparisons were performed with the sole use of experience and memory by expert dermatologists. A feature becoming more and more recognised as highly valuable is the ability to communicate over the Internet mole images to remote expert centers in order to obtain a second opinion, almost in real time.

It has been proved how specificity in assessing melanoma achieved using digital dermatoscopy is significantly higher than the one achieved using traditional dermatoscopy. [51] This means that not only digital dermatoscopy leads to a higher rate of melanomas correctly detected, but also the number of moles incorrectly marked as melanoma is reduced, thus avoiding unnecessary surgery. Specific training in the use of a dermatoscope can further improve diagnostic specificity.

Due to its advantages digital dermatoscopy is becoming ever more widespread. Studies demonstrate how automated diagnosis based on digital dermatoscopic images can match or even surpass human accuracy [20]. The number of publications proposing novel approaches and applications is rapidly growing. Many commercial products can be found nowadays on the market, even if they are predominantly targeting large scale, highly advanced institutions and medical research centers. The next sections will give an overview of the current state-of-the-art in commercial systems for digital dermatoscopy.

1.4.2 FotoFinder

FotoFinder can be regarded to as the leading brand in digital dermatoscopy. The German company FotoFinder Systems GmbH was founded in 1991, and can therefore take advantage of more than twenty years of experience in medical imaging systems. Its fame as a high-quality manufacturer gained popularity in the scientific community, which helped spread the company's market footprint worldwide.[1]

It currently offers four main product lines, with applications ranging from digital dermatoscopy to clinical trials. Its flagship solution remains the FotoFinder dermatoscope, to which the brand is universally associated. The FotoFinder dermoscope is a combination of hardware and software that enables body mapping and digital dermatoscopy. It comes in four different bundles, targeting different volume constraints, power demands, and price points.

From the hardware point of view, the top-selling, classic version is built starting from a digital camera. The input device is placed, for ease of pointing, into a pistol like casing including a light source and a dermatoscopic lens with 20x to 70x zoom. Although regular immersion epiluminescence is the default dermatoscopic technique, optional gadgets allow polarized light and fluorescence diagnosis. The camera can be placed into a docking station, and it is linked to a custom-encased desktop computer via cable. A standard flat-screen monitor, mouse and keyboard are part of the kit,

[1] http://www.fotofinder.de/en.html

which comes with a specifically designed moving stand (figure 1.2).

From the software point of view, the FotoFinder platform consists of a central database engine, and three software plugins for different imaging applications: *dermoscope dynamic*, for digital dermatoscopy; *mediscope*, for consistent 'before and afters'; *bodystudio*, for Total Body Mapping. *Bodyscan pro* allows automated detection of new moles. Camera settings can be controlled live using the *CamControl* application. In addition, the *Moleanalyzer* pattern recognition software, developed at the Dermatology Department of the German University of Tuebingen, provides dermatologists with a malignity score for an instant second opinion.

An expanded bundle, called *dermoscope tower*, embeds a stand and a laser pointer to improve reproducibility of patient pose and full body photograph distance and angle. On the other hand, the single software and hardware modules can be bought individually, and integrated with pre-existing instrumentation as a personal laptop. A recent reincarnation of *FotoFinder dermoscope* as an iPhone application, marketed under the name of *handiscope*, and the newly engineered companion dermatoscopic lens embedded in an iPhone cover, have been heavily promoted.

It is clear how FotoFinder's extensive offer covers a wide range of needs. Notwithstanding, as will emerge from interviews reported in later chapters, user satisfaction is not complete. From a hardware point of view, one main concern until the last version of the FotoFinder was poor camera resolution: this issues has been recently addressed by the adoption of a HD (High Definition) camera for the latest model. Moreover, although the custom "gun" case accounts for easier pointing, it makes the camera bulky and its unwieldy; such a difficult manipulation is worsened by the presence of cables. Additionally, the trolley containing the whole system has considerable volume and weight, and it is difficult to be placed and moved around the consultancy room. Another problem regards the choice of standard epiluminescence as a default dermatoscopic technique: mounting and dismounting lenses on the "camera-gun", and subsequently transferring to type on the computer's keyboard becomes a messy process when immersion oil is involved.

The most serious flaw according to the dermatologists we interviewed is lack of usability of the bundled software. The most apparent manifestation of the problem is that an additional person is often required to follow the procedures on the computer screen. Mole marking and identification is non intuitive. The diagnostic information input and retrieval is burdensome. In general, mole data migration from one office to another is almost impossible.

FotoFinder remains the market gold-standard for digital dermatoscopy. Its four product lines respond to vastly diverse dermatologic skin imaging needs. However, specialists ask for a more usable, portable, time-efficient tool suite.

Figure 1.2: The model of the FotoFinder dermoscope that was used by the interviewed dermatologists. Source: *http://sergiovano.blogspot.it/*

1.4.3 MoleMax

MoleMax is the first integrated system for digital epiluminescence microscopy and full body imaging in the world. The first units were released in May 1997. MoleMaxII was developed jointly by researchers at the Department of Dermatology, University of Vienna Medical School and Derma Instruments.[2]

From a hardware point of view, MoleMax does not differ substantially from FotoFinder. The main structural difference might be the use of multiple cameras for different tasks. The latest MoleMaxIII features three cameras, one for videos, one for dermatoscopic images, and one digital camera that can be used for both. Custom-encased cameras appear to be smaller in size and more ergonomic than the ones found in FotoFinder

[2]http://www.dermamedicalsystems.com/

systems.

Among the features presented by the software, many take a different route in module composition, and subtask emphasis, but the main capabilities are preserved. The software is partitioned into several modules. The *real time/overlay follow up* provides a side-by-side or overlay reference image for comparison and for replicating image posture. The *trending and monitoring*, that provides a complete patient image history in chronological order coupled with the appropriated comments. A *histopathology* module can import histopathology images into the patient database. *Expertizer plus*, the core module, includes image analysis functions. The *molescore* module can be used for automatic scoring of moles. An additional module can perform automatic mole count on two follow-up image of a same body site. A total body mapping module is also present.

As with FotoFinder systems, MoleMax main components come packaged in different form factors, in order to support different portability and value-for-money demands. The use of multiple handsets avoids the need for lens switching between full-body and dermatoscopic images. This is a trade off with the volume occupied by the system, and consequently portability. In particular, only in the most recent product, *MoleMax HD*, an LCD is embedded in the input device for live preview.

1.4.4 Dermox and Galileo

One of the dermatologists we interviewed pointed out that his institution had adopted a more “homespun” solution. As it is a cost-efficient approach, its likely adoption in less funded clinics makes it an important case study.

The system is composed of separately sourced elements. A regular digital camera is coupled with a dermatoscopic lens through a commercially available mounting ring. Doctors can transfer images to the computer *a posteriori* through standard USB. Images are then imported in an assisted reporting system specific to dermatologic applications; in the covered case the software used was Dermox, developed by Amplimedical, Casti Imaging Division.[3] The computer program performs basic database, preformed report filing, and image gallery duties, as well as more advanced operations, as colourimetric and dimensional measurements, and side-by-side comparisons. In addition, the system supports real time image acquisition.

[3] http://www.amplimedical.191.it/Dermox.htm

For final archival of Electronic Medical Reports (EMR) internal policies required a further step. Noemalife Galileo has been endorsed by Veneto region as the common platform for EMR management in public hospitals and clinics.[4] Although centralised and standardised information management is a crucial step forward in public healthcare governance, its top-down adoption mandate is mainly regarded as a bureaucratic decision, more than as the introduction of a crucial IT support tool. Few efforts have been made to integrate Galileo with most previous software, as well as software currently under development. Its isolation from central processes involving patients, including but not limited to visit booking, makes it a burden to routine use.

The use of a completely separated camera accounts for completely wireless image acquisition and transmission. The other more complex systems provided this ability only in the most extended, or in the most limited versions. Even though the assembled system permitted all basic functions provided by specialized instrumentation, the fact that the components were not engineered to work together causes problems. For example, the system does not enforce predetermined focus and zoom policies. Thus a single change in configuration parameters can make comparison with all previous images impossible.

1.4.5 Limitations of current solutions

Digital dermatoscopy introduces many proven advantages in dermatologic daily practice. The set of support tools and services is expanding the scope of traditional diagnosis. The main benefits of digital epiluminescence dermatoscopy are:

- standardised total body photography
- full body photography of lesions
- polarised and non-polarised dermatoscopy
- total body photograph comparison
- sequential dermatoscopic imaging
- computer assisted diagnosis
- fully automated diagnosis

[4] http://www.noemalife.com/soluzioni/area-clinica/ehremr/

- teledermatology

Despite its innovative features, digital dermatoscopy fails to empower dermatologists. Current state-of-the-art technology tends to scatter functionalities in different modules, in order to appeal to wider audiences. While this approach allows individual marketing of different services, operations are scattered and do not pattern themselves according the doctor's workflow. Interruptions, context deprivation and memory waste are some of the inherent defects to the constant switching of hardware and software components.

The common mitigating strategy companies adopt is hardware duplication, to make each task correspond to a unique specific device, instead of different configurations of the same device. The resulting systems are bulky, unwieldy, and expensive. Moreover, software usability is in the end the most significant cause of loss of focus and loss of time during visits.

The general consensus seems to be that streamlining and high-efficiency are incompatible with portability and ease of use.

Chapter 2

Cutis in Silico

Even though current state-of-the-art technologies in digital mole mapping aim to support higher quality medical examinations, the lack of usability in such systems negates their potential advantages. One of the main factors that makes most digital mole mapping systems unusable is an exaggerated stress on completeness of input information over information flow. The situation is often aggravated by unwieldy physical machinery, intrusive even for major hospitals. The performance of human agents is thus impaired. The negative results are reflected in both the increased average time required for a visit, and the reduced individual productivity of attending personnel - an additional operator is often needed to manage the equipment. The overall expected benefits of an automated support device are effectively neutralized.

To address these issues, the Department of Information Engineering, University of Padova and the Dermatology Unit, School of Medicine started a new collaboration to develop a fast, accurate, usable system for mole mapping and computer assisted melanoma screening. The project was named Cutis in Silico (CiS) to stress the role of automated image processing. CiS is designed as a modular, expandable system. Its modularity enables adoption by a wide range of users, from small consulting rooms to thousand-patient clinics. It is designed to empower the single dermatologist with tools for higher quality and productivity, as well as boost efficient teamwork. It is a complete package to assist the doctor throughout the whole course of the visit, and more importantly allowing long term, continuous remote monitoring of the patient.

For the time being CiS is in a concept design phase. Different theoretic image processing approaches, which are the base of the system, are being evaluated and tested.

2.1 Structure

The architecture of CiS comprises three main components. Each of the components is an autonomous system designed individually for a particular phase of the visit and its follow-up. When all three components are used in cooperation, however, an extensive, seamless tracking of the patient's condition is achieved.

The three main components of CiS are temporarily called *mole mapper*, *body scanner*, and *personal screener*. In one sentence, mole mapper is a support tool for dermatological visits, the body scanner a complete figure photo booth and mole mapper, and personal screener is a low-cost, portable instrument allowing individual patients to acquire "at home" dermatoscopic images of lesions deemed suspicious by their dermatologist.

Even though the three main elements of CiS can be used independently, they can operate together with a high level of synergy. A self-synchronizing centralized data management system offers complete and up-to-date information from all devices, even across multiple laboratories and multiple dermatologists visiting the same patient.

This thesis is positioned on the end-user side of the prototyping spectrum, focusing on user experience, in order to identify and code feature relevance and interaction patterns. As mole mapper is the cardinal interactive element of CiS, as well as the most complex and complete, this work focuses on its development. Body scanner and personal screener will be further discussed, but are currently of lower priority in the project.

2.1.1 Mole mapper

The first of the three components of the CiS platform, the mole mapper, is the core of the system. It is designed to be used primarily by dermatologists, supporting them during the typical working day. It also serves as a main interface and processing hub for data produced by the other two subsystems.

A typical session of use of the mole mapper spans a single visit, from just before the patient enters the office, to immediately after the visit report is printed. Mole mapper can access patient files through a phone-book-like archive, and manages appointments via an inbuilt agenda, summarizing important information from the case history and recent updates on patient's condition. It provides means for taking full body images of the body surface, for guiding the dermatologist through the acquisition of dermatoscopic images of individual suspicious lesions on each body portion (a daunting task for patients sporting over a hundred lesions on e.g. their torso alone). As soon as a full body image is acquired, whole body mole segmentation takes place; previously marked moles are then mapped to the new visual reference; the skin is finally scanned for the appearance of new moles. Dermatoscopic images of marked moles can be as well compared to previous images of the same lesions, or to images of other lesions from the same patient. Clinical reporting is automated to reflect the status of the visit and the institutional standards.

The high level capabilities featured in the mole mapper reflect and expand the skills of the dermatologist. The goal is not to replace the human operate, but to help him reach higher levels of accuracy, efficiency, confidence.

As noted during user research, although the steps performed during a visit are homogeneous between most dermatologists, there is no publicly accepted standard in methodology for acquisition of clinical data. This frequently leads to compromises in quality or comprehensiveness of input data, made to shorten visit duration; this can be problematic, as even lesions few millimeters in diameter risk being "cancer seeds". Furthermore, non standard body pose and non standard subdivision of the body can make older images useless if the patient has been seen by multiple physicians with different personal conventions. *Mole mapper enforces a standard, considered acceptable by all interviewed dermatologists, in acquisition of full body images. It proposes a set of standard poses for the patient, without ruling out custom shots, needed in special cases for difficult-to-reach body surface spots such as interdigital space.*

Even fairly recent digital dermatoscopic cameras integrated in expensive systems suffer from low fidelity image acquisition. This can misleaded the human operator into making incorrect diagnosis. Moreover, automated tasks such as segmentation, that form the basis of diagnostic support, become inaccurate. In practice several dermatologists prefer for this reason to undertake visits and formulate diagnosis using the traditional analog, handheld dermatoscope, using digitization only for final documentation, if at all. The potential benefits of diagnostic support devices are considerably reduced, while the time required to complete the visit is increased. *Mole mapper offers high quality dermatoscopic imaging, allowing more accurate analysis compared to inspection through the naked eye and/or a handheld dermatoscope.*

Current market leaders in digital dermatoscopy have integrated into their systems the domain knowledge received in years by clients and obtained through collaboration with field experts. Lately automated diagnosis has been added to the capabilities of their software. From our research it emerges that performance of such algorithms still tends to be fairly low compared to human operators. More relevantly, we found that highly regarded practitioners of the field have very low confidence in automated diagnosis. *Mole mapper, instead of providing diagnosis, highlights relevant clues, and suggests statistical evidence when appropriate, boosting the performance of dermatologists instead of attempting to replace them.*

Mole mapping is a task that requires extreme attention to detail and memory over an extended period of time. In addition, current schedules in public hospitals impose hectic schedules during the whole working day. The concept of a rigid, detailed and complete dermatoscopy machine of the current competitors creates additional difficulties to daily practice, as it undermines cognitive focus and interrupts workflow. *Mole mapper provides intuitive support to keep the doctor "on track" during the visit, and helps him reach all necessary information without effort.*

Even if mole mapping and follow up visit schedules are frequently overbooked, the population that actually receives screening is significantly lower than the population at risk of skin cancer. For the minority that did receive screening, average follow up time is often dilated. Average visit time is therefore a crucial index in evaluating the ability of a medical center to cover the need for healthcare. The cumbersome process coerced by current technology, although coherent with theoretical dermatologic doctrine, derails the visit workflow, undermining process continuity by burying the dermatologist under a plethora of useless data. *Mole mapper provides a streamlined workflow that permits professionals to meet hard deadlines without compromising diagnostic quality. Yet, it is flexible enough to support any visit organization a doctor finds natural, sporting the highest level of detail when required.*

2.1.2 Body scanner

The body scanner can be seen as a subsidiary asset to the mole mapper, even if it is intended as a stand-alone device. It takes high resolution photographs covering almost the entire area of the patient's body in a fraction of a second; from these, it then reconstructs an accurate 3D model of the body surface [37].

A considerable overhead in each visit is getting the patient naked and obtaining clear images of his body. Nevertheless, it is unavoidable to take reference images of the skin for two main reasons. First, it is essential to precisely document the position of pathological and suspect moles in order to avoid misunderstandings when communicating an excision to the surgeon. Second, one of the main clues that lead to melanoma diagnosis is the appearance of a new macula on the skin (melanoma de novo); it is estimated that the incidence of cutaneous melanoma that develops from a pre-existing mole is as low as 20% of all cases (melanoma ex naevo). It is therefore essential to detect accurately and in advance the appearance of new lesions - which requires both a historical archive of reference images, and a precise comparison algorithm. [8] *With the body scanner it will be possible to automate image acquisition and historical comparison of almost 100% of patient's skin surface, while cutting on the time costs of taking the full body images manually.*

2.1.3 Personal screener

The last component of the CiS platform is the personal screener. Personal screener is used by patients to keep track of the evolution of moles in a follow-up program with minimal expense. Comprised of a software element and a dermatoscopic lens, the personal screener kit contains an easy-to-use index of interested moles, and allows photograph management, as well as basic automated evaluation of mole image parameters, possibly notifying the user if urgent dermatologic consultation is suspected necessary. All patients, dermatologists and clinical institutions will benefit from the use of personal screener. Patients will be able to monitor the condition of their moles in between follow-up visits. Dermatologists will gain precious documentation of the evolution of lesions. Healthcare institutions will be able to match the optimal time resolution for screenings. *Personal screener will provide end users with more frequent screening at a modest price, filling the gap between follow-up visits, and increasing the chances of early melanoma detection and favorable prognosis.*

2.2 Platform

The CiS project will be powered mostly by Android[1], a Linux-based operating system for mobile devices, developed by Google in conjunction with the Open Handset Alliance[2]. There are many reasons for this.

[1] http://www.android.com/
[2] http://www.openhandsetalliance.com/

We chose Android over other platforms as the basis of the CiS project, since it proved to be the most versatile on the market, and the most capable to simultaneously handle the mole mapper, the body scanner, and the personal screener. Our main performance metrics were:

Expandability The long-term vision of CiS is that of a system that adapts to its environment. To reach its maximum potential, it should integrate the working place in a pervasive but non-intrusive way. It should, first and foremost, be able to expand to different form factors and devices, to allow upgrading when a specific need arises.

Single user, multi user Should mole mapper and/or personal screener be used by individual or multiple users? We are still discussing the issue. Dermatologists can work either singly or in teams. Personal screener will as well be targeting both individuals and families. The most likely interpretation of reality is that these two user management approaches cannot be used exclusively; thus a solution that supports both was preferred.

Reusability of code The three CiS components share some tasks. An example would be the image processing techniques, such as dermatoscopic segmentation algorithms, that are used by both mole mapper and personal screener. It is therefore essential to be able to reuse the same code in different components.

Probably the most important factor in the choice was the suitability of Android as the platform for the mole mapper. As mole mapper is the principal element of CiS and the central component of its operations, it is the unit sporting the largest specification intersection with the other two components. What follows is a summarized presentation of high-level essential provisions, that are in fact shared in varying proportions by all CiS platform devices.

The majority of the time spent visiting a patient is taken by observation of the lesions, either "naked eye" or through a dermatoscope. It is therefore essential to present a reasonably large screen. In addition digital photograph quality should be good. One of the main advantages of a digital dermatoscope is virtually unlimited zoom on important details - provided images are of high enough quality. Furthermore, it has been noted how a dermatologic checkup is a data-flow-driven task. Intuitive navigation is imperative. This aspect will be more thoroughly discussed in the next chapter. In addition, dermatologists often change consulting rooms - whether in the case of a private practitioner, or the case of a public clinic where the doctor might be relocated to a different room for contingent needs. A certain level of mobility is needed for all CiS components. Device maneuverability is even more important to access all portions of the patient's body. The absence of cables (replaced by wireless connectivity) is an important issue in this regard.

It is clear how the choices converged to mobile platforms. Of the leading technologies, Android supports the largest variety of devices, from smartphone and tablets[3] to television screens and set-top boxes. Most major camera manufacturers also have announced Android compact cameras in the near future, some of which will reach market in the near future [4].

The mole mapper will be implemented as an Android tablet. This solution represents the optimal compromise of a portable, handy device that allows natural interaction while preserving high quality image acquisition and presentation. This choice is also a good match to the user experience vision formulated in the next section.

[3] http://www.journalism.org/analysis_report/device_ownership

[4] For example, the Nikon Coolpix s800c, the Samsung Galaxy Camera, and the Polaroid SC1630

Chapter 3

Users

Understanding how dermatologists relate to dermatoscopy allows to define guidelines for a consistent interface. Irrespective of the object of the design, knowing the user is paramount for paralleling his expectations with effective interaction. [6] The point of view of the user regarding his personal goals, his outlook on the environment the device will be used in, how the processes involved are organized in his mind, are the often unwritten presumptions that motivate him use technology. Capturing this information is therefore essential to create interfaces that enable the user fulfill his intents.

The goal-directed design methodology is acclaimed for its remarkable results in providing consistent, focused user experience. It was first introduced by Alan Cooper, whose best selling book About Face [10] is now in its third edition. Interaction design is now established as an autonomous discipline, although it draws from accomplishments in fields such as social sciences, cognitive psychology, and industrial design. The founding principle is that software does not allow users to infer its affordances directly from its internal structure, as it was the case with mechanical products; a presentation layer that reflects the mental model of the user on a task-related basis will therefore lead to a more spontaneous interaction.

While a vast amount of applications would benefit from intuitive interaction, it is indispensable when enabling users to be highly efficent is the primary objective [12]. In these cases, in fact, the ability to reach goals effortlessly is the key to satiate the anticipation of the use of technology. As such, the pleasure deriving from usability greatly surpasses the pleasure deriving from sole aesthetics. User (and consequently stakeholder) long-term satisfaction is the utmost metric for success of usability design.

3.1 User research

User research is meant to provide designers and developers with insight on what are the goals of the product from a human-centric perspective. It covers aspects of the application domain, the constraints of the problem and the nature of the users in depth, and it confronts them with both the intents of the design and the targets of the commissioning entity. The outcome of the research is an indirect codification of the extended requirements for the design, which is comprehensive of the complex and often ambiguous human situation, yet which is posed in a way that is easy to refer to during the development process.

Research is often associated to quantitative figures and statistics by a popular stereotype. In particular, numbers that result from market analyses are to engineers a comforting ground truth, despite their interpretation might differ wildly and lead to misconceptions. While quantitative research can sometimes be useful to support certain business decisions, projecting the human behaviour on a reductive set of axes in most cases leads to the lossy quantization of nuances that are in fact essential to design.

In example, quantitative research cannot be employed in replying to questions as:

- How does the product integrate in people's everyday lives?
- Which are the causes that motivate people use the device?
- What are the basic tasks that people perform in order to satisfy such causes?
- What problems are currently interfering with people's approach to the relevant tasks?
- What do people using the device consider as compelling experiences?
- How can the device offer such experiences in its field of application?

The real-world human activities and relationships are complex, time varying, subjective. Social scientists and anthropologists have long been developing qualitative procedures that capture in rich detail such phenomenologies, to come to a deeper comprehension of the human nature. Usability designers productively borrow such tools for the far more limited and pragmatic scope of creating products that meet user needs.

While qualitative research doesn't understate the importance of the technical, business and environmental contexts of the product to be designed, it enables as well a circumstantial exploration of attitudes and aptitudes of potential users. It is therefore particularly apt to highlight behavioural patterns in a faster and more defined way. The information gained through the process exhibits an unprecedented completeness in regard to interaction design.

User research alone is however usually not an adequate source for obtaining sufficient qualitative data to buld a design framework. The information coming from a single source is in general partial. Moreover, during interviews users tend to see themselves as designers, and their subconscious abstraction processes filter and distort their responses to harmonize with what is their personal immaginary solution. One common pitfall of user research is in fact to accept solutions from the users, without first questioning the originating problem. This is mostly due to users having a biased comprehension of a device, determined by how they currently use it. Implementing such supposed improvements may introduce further incoherence with the mental model of the goals and tasks. This is one of the reasons why multiple, qualitatively different points of view should be queried, in order to build a comprehensive model. Some methodologies that target different sources that Cooper has experimentally found to be the most useful for qualitative research are:

- Stakeholder interviews: The interpretation for "stakeholder" in this context includes figures in responsibility for the product being developed as executives, product managers, marketing and sales representatives. The aim of such interviews is that of obtaining information regarding product vision, budget and schedule, technical constraints and opportunities, business drivers, perception of the user. This enables the designer to know what are the virtual and concrete materials he will be asked to use, their capabilities and limitations.

- Subject matter expert interviews: For subject matter experts it is intended the field personnel that is able to provide feedback regarding the specialized domain the product will be used in. These interviews will provide information on best practices, regulations, and user roles and characteristics from a power user point of view.

- Customer interviews: Customers are differentiated from users in that they represent the individuals that make the decision to purchase the product. In scientific and specialized domains in particular it is common that customers do not belong the to user group. This kind of interviews is intended to assess what are the goals in purchasing the product, and the frustrations with current solutions, the decision process that leads to a purchase.

- User interviews: Users are the people actually using the product, or potentially could make use of it. They represent the main focus of design efforts, as it is their goals that need to be effectively satisfied. As such the information that user interviews must collect ranges from context, domain knowledge, task comprehension to goals, motivations, expectations and mental model.

- User observation: It is often far more meaningful to watch the user perform the tasks in the context that would involve the product than inquire the user for a description.

- Literature review: Usability designers should not be dispensed with going through traditional paperwork and gather through manuals, white papers, business plans, marketing surveys, technical journal articles, and web searches. Such data is needed prior to assessing other interviews, as it provides base domain knowledge and vocabulary to entertain more fruitful information exchange and develop more precise questions for users and subject matter experts.

- Competitive audits: It is useful to perform heuristic or expert review of competitor interfaces, and bring them into comparison with the proprietary interface throughout the development process. Interaction and visual design principles can be a useful metric system for differentiating and evaluating both proprietary and competitor interfaces.

The application of such methods to the case of mole mapper is somewhat troubling. The main reason of concern is the number of people that are the target of the first dissemination attempt. Mole mapper is essentially built for order of tens lead users, that is, researchers and academics, and order of a few thousands final users, that is, avant-garde public and private clinics. It is nonetheless almost impossible to obtain iterated, frequent access to top-tier busy professionals, as it would have been auspicable instead. In addition to that, the field of application the mole mapper is highly specialistic. Technical details can therefore “make or break” the usefulness of the interface. Moreover, the groups of users, customers and stakeholders in the particular case of mole mapper reveal nourished intersections. While the information provided by interviewed people is in fact corresponding to that of multiple sources, the commixture of contexts renders difficult to formulate a meaningful interpretation.

Qualitative research must be adapted in order to correctly interpret information from mixed-context impersonations. It is needed to develop a methodology that individuates the specific goals and pieces of information, and separates them into the semantics of the different roles. It is also needed for this methodology to be tolerant to uncertainty, partial information, continuous information integration.

Design integrity is a matter that Rebecca Wirfs-Brock covers in fine details in one of her most applauded papers [53]. It mainly deals with how to conceive robust software design that supports and adapts to the refactoring process that is at the base of agile development strategies. As a matter of fact I believe it can be consistently applied in the process of adapting core design decisions to incremental information provided by different, mixed sources.

The main accomplishment of Cooper's technique is in letting goals, instead of tasks, direct interaction design. Goals are defined by the entire life experience of the users, while tasks are only bound to the specific working and position context. Satisfying goals instead of tasks helps provide solutions that go beyond instant gratification, and that solve the originating problem in current competitor designs. To be able not to overfit to the single person, it is essential to obtain complete information to accurately segment the user population based on the goal feature. When information is not complete, it is easy to be mislead in individuating the high level goal, in example being tempted to stop at a target that is truly intermediate. As goals are at the base of the design process, misinterpreting drivers in the beginning may spoil the whole subsequent phases. If the sources of information are represented by the same limited pool of individuals, while it is true that all points of view are represented, the common interviewing practices cannot attribute a specific goal to the particular facet of the interviewed person it arises from. It is nevertheless often achievable to separate the facets following the Role, Responsibility and Collaboration relationships between them. It is therefore possible to reconstruct *a posteriori* a map between goals emerged during the observation phase, and the otherwise unacknowledged information sources.

All along the information gathering phase, and in the period immediately following, placeholders for the information sources discussed above were put under test. Specific roles were given to the placeholders, collaboration contracts between them were defined, and responsibilities for technical, organisational, data-related aspects were distributed. As data was input to the system, and distributed to the placeholders, the subdivision of the placeholders and their definitions was checked for coherence; the definitions presented above are the one actually used.

The data disposed naturally in the model in most acquisition iterations; only minor changes in the definitions of the roles and relationships were needed, and such modifications were confirmed as more stable in subsequent analyses. The interpretation for empirical analyses at Cooper's revealing the particular qualitative research methods to be more significant might be that in fact they are not only significant in isolation, but also the personification of their sources attest a strongly linked information network as a whole. In fact, the innovation of the proposed approach consists of anticipating the introduction of a variable set of adaptable personas to the research phase, so that partial and mixed-source knowledge can be put into context basing on the information providing drivers. Personas will be discussed in fine details further in section 3.3.

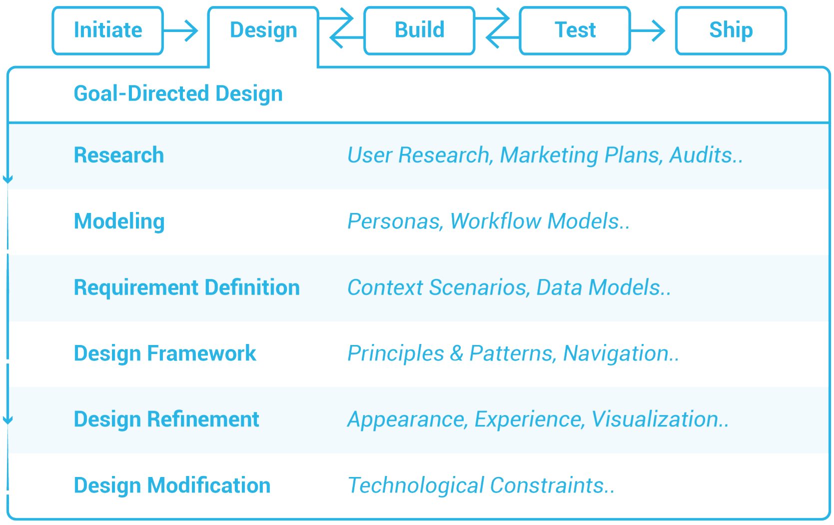

Figure 3.1: The Goal-Directed Design process

From this systematic social model the designer is able to restore multiple keys of interpretation. The fact that the roles we all impersonate in everyday life can be represented as interweaved multiple agents is a commonly accepted notion. Yet this approach differentiates itself in that the designer assumes an architectural posture in defining what the sources are, and more importantly what are the margins of error in the attribution. As a matter of fact, such an attribution was implicit in targeting particular categories in previous qualitative research methodologies. Moreover, the fact that a chosen subdivision would be effective and complete was justified only by intuition and prudence, as it did not check for broken links in information structure. Further, non-trivial patterns that crossed the single views were difficult to assess, as associations were inarticulate. It is important to acknowledge the constructive responsibility the designer has in defining solutions. While it is essential to preserve an objective posture in individuating goals, in situations where information is ambiguous or lacking its reconstruction and interpolation must be guided by context, and matched against misinterpretation probability. Accepting the fact that the designer might have an engineering attitude in the analysis of goals and creation of solutions leads to a more coherent and robust design.

3.1.1 Interviews

Interviews with five dermatologists were performed during a two-month period. Two of the dermatologists involved were amongst the most praised professionals on a national scale. One was the one that supposedly performed the largest number of mole mappings in different thousand-patient clinics during the last years. The remaining two that were interrogated were medicine students in the latest years of specialization. They were all associated with public health and university institutions, in the departments of dermatology, oncology, pediatrics. Most of them were currently performing or had previous experience as private practitioners as well. They were all trained in dermatoscopy, and had at least been exposed to digital dermatoscopy; the majority routinely used digital dermatoscopy systems for mole mapping and diagnosis purposes. Three of them were female. The age of the participants covered most of the professional life-span of a physician.

Further information was acquired attending a specialist conference on the theme of advanced dermatoscopy techniques. Approximately two hundreds students, private and public health practitioners, biomedical technicians and health institutions management board members appeared at the conference. The demographics of the audience attested an even more pronounced variety. Besides gaining in-depth domain knowledge, and recording best practices and common views of tasks, patients and technology, it was possible to attest the collective behaviour of the target population of dermatologists. Moreover, participating in informal discussions permitted to obtain crucial yet otherwise unapproachable details.

Essential data was additionally obtained via direct observation of dermatologists in their workplace. One member of the development team volunteered to undergo mole-mapping performed with a digital dermatoscope, on a monthly basis for a year, by different physicians, for the purpose of clinical studies on the evolution of naevi. During the visits he was able to capture the subtle nuances of the real-world practice. He could also gain a better comprehension of the state-of-the-art technology, and the disadvantages of current human-machine interfaces.

What follows is a sketch of the primary information obtained, projected into the chosen role-models. Data has been deduplicated and presented only in the most relevant perspective for the sake of clarity. The raw observations will be then elaborated in the end of the section.

Stakeholders

- Mole mapper will be the flagship product throughout its life. It therefore needs to be conceived from origin with high quality standards in mind.
- The customer segment the mole mapper is primary targeting is that of medium-to-big-size healthcare institutions, to diffuse on a second expansion phase to privates.
- The device is seen as the base of a platform, and its market penetration bridgehead. The strategy employed for the complete system will substantially align with a reverse razor-and-blade approach, but permitting full operability of all components.
- The users of the device will be academic and leading specialists. They represent the vanguard of the discipline, and are regarded to as experts in the field. While they are utterly knowledgeable in their field, they are not considered to be particularly hi-tech.
- The impression of users is that they do lack systematicity. A boost in efficency is perceived to be a great value to them.
- To smooth the initial learning curve and empower user to obtain higher efficency in short time, user training is intended to be provided.
- After-distribution maintenance must be kept as low as possible, as there is a single small team engineering the device, managing the project, and keeping relations. For that reason, it is highly preferred the use of known mobile platform with native high support.
- The unit cost should be low, as profit is not the target of the stakeholders, and the initial investment must be restrained. However, considering that the competition is established on far higher price points, and there must be no compromise on quality, a reasonable extension in budget can be asked for.

- The device needs to be compact, natural to interact with, easily connected to respond to user demand and meet the marketing goals. The tablet form factor is thought to be the best option.

- The first realization of mole mapper must be restrained to a single comprehensive device. In fact, it will need to adapt quickly as market is explored. Considering the highly innovative approach, and the unknown reaction to its features, it might undergo even radical refactorings in short time.

- Polarization technology for dermatoscopy is the far preferred choice, as it eliminates the several disadvantages that immersion oil brings. There is no sound proof of inferiority in comparison to regular epiluminescence, and market research does not lead to a unique, motivated preference in the users.

- For the time being, developing automated diagnosis techniques seems to be an uncalled for embellishment.

- A functional prototype should be in hands of possible clients by the end of the year; it should however be sufficiently complete to be able to perform all main tasks offered by the mole mapper. It should also be a convincing carrier of the novelties introduced, even if not in its final form.

- The development/management team is in association with a University department. It therefore holds in high regard demonstrating its reputation, innovativity, and top quality.

Subject matter experts

Best practices and applied field theory

- The people attending the visit range in number from two to five, patients included. In the most usual configuration, a senior dermatologist is paired with a postgraduate student, or a second dermatologist. A nurse is also typically involved. The in-depth screening and diagnosis are performed by the most experienced dermatologist. The second physician or student may as well perform a preliminary screening, but it is in particular assigned to operating the computer with the dermatoscopy management software. The nurse often takes the dermatoscopic and full body images for the record.

- The composition of a visit varies, yet the main parts, as one outlined in the first chapter, are: revision of the patient's report, comparison between old full body photographs and skin of the patient with naked eye to scan for new lesions, dermatoscopic examination of single lesions, marking of suspicious lesions, comparison of previous and new dermatoscopic images of lesions that are suspicious or in follow-up, diagnosis and prescription formulation, and composition of a visit report.

- Diagnosis is based on qualitative criteria as ABCDE and the 7-point checklist, and rely mainly on the experience of the dermatologist.
- An emergent approach it that of the ugly duckling. Its cause of success is taking into consideration the overall lesion characteristic in the patient: if all lesions present unusual characteristic, it is highly unlikely all of them are malignant.
- Dermatology schools underline the importance of an historic comparison of naevi to be able to assess the presence and interpretation of their evolution. A functional history management of dermatoscopic images would be a great support tool.
- There is no standard subdivision of the patient's body into segments that correspond to full body photographs. As the patients are more often than not visited by different dermatologists in follow-ups, such lack of a standard makes comparing full body photographs impervious.
- The diatribe between polarized versus regular dermatoscopy is still open. Most interviewees had strong feelings on the matter, yet discordant and often not supported by a demonstration on why the alternative approach would be inappropriate.
- It is rare, but not neglectable, that extraordinary situations pose technical difficulties to digital dermatoscopy. In example, moles in the interdigital spaces require special lens adapters; huge lesions can be bigger than the lens, thus rendering impossible to capture them in a single photo.
- Image quality is essential in supporting accurate diagnosis.
- There is no coherence on the information provided regarding the average visit time. The shortest expected time for a full body mapping is 15 minutes, with the typical time being supposedly 30. Patients with up to hundreds of lesions can require indefinite time - it is likely that single visits rarely exceed one hour. Most dermatologists in public structures have full-day working days, divided into morning and afternoon turns.

- Rich annotations should be useful to integrate visit reports with contextual information, such as whether the patient was excessively exposed to sunlight before the visit or is pregnant. Moreover, melanoma assessment is built on tactile features as well as visual ones.

- The competitor FotoFinder is identified as a tool for documenting, not a support to analysis. The reason for such statement is that it is unusable in practice.

Perception of the user

- One major concern for the user is making sure to avoid legal action by the patient. A patient could file a sue for condition understating, mistreatment, hiding information on his health, privacy issues. This fear goes beyond a rational motivation, as the individual responsibility of the clinician is in the end backed up and absorbed by the employer institution. Yet, the doctor would feel its authority posed at risk.

- The skills needed by the dermatologists are not felt to be transferrable to a machine. This concept comes from the fact that little objective measurement is used in common practice. In general, there is little trust for technology. Users, as well as subject matter experts, subconsciously prefer not to subside authority, and fear of being replaced by a machine.

- Most users don't take full advantage of advanced or lateral features that current systems provide. This is due in part to the fact that such products are time consuming to use, in part for the presence of internal standards and regulations that cannot be ported into such systems.

- Virtually all dermatologists like to possess technological devices, as they support their elevated image of self, and are useful for letting the patients know they are in expert hands.

- Users, in particular those that use the devices infrequently, tend to lack systematicity.

Real-life considerations

- Considering that skin surgery rarely has outcomes more serious that a scar, dermatologists tend to resort to excision just for precaution, whenever suspicion rises for a lesion. This behaviour is aggravated by the fear of legal action.

- Most diagnoses are assessed based on heuristics and impression; this fact is one of the reasons why they feel personal experience cannot be coded into algorithms

- Few dermatologists actually inspect all naevi, considered the time constraints. They limit to few lesions that stand out of the rest, mainly because of their pigmentation or size, and to some sampled regular naevi, for comparison.

- The rule of thumb is that it suffices one indicator feature that is not aligned with a healthy profile for marking a lesion as suspicious.

- In reality, a lesion is taken under consideration only in two, at most three visits. If after a follow-up the lesion is still perceived as suspicious, it is surgically remove; instead, if it appears normal, its “suspicious” mark is definitely cleared.

- At each visit typically two to four naevi are elected for a follow-up. They next visit should be scheduled in four to six months, but in practice it mostly comes down to a year, considered the overbooked state of facilities.

- Most dermatologists never actually take full body photographs; they limit themselves to compare the patient’s skin with the oldest photograph in their archive, “in order to maximize the difference between the two”.

- Few dermatologists have a comprehensive grasp of the statistic figures and use them directly.

Context

- There is much confusion on the subject of patient data. While it is owned by the healthcare institution, it often is asked for by the patient. Data cannot be moved without the consent of the patient, yet for research purposes and/or with proper anonymization the reported photographs might be used. Teledermatology is still a mirage, as legislations are not following the pace of times. In reality, much is copied, moved and shown informally when considered responsible and reasonable.

- The internal management of patient visit schedule and profile is scattered into different services, applications, offices, regulations.

- all other information provided in chapter on dermatoscopy

Customers

- Customers are executives in charge of top-tier healthcare structures. They are dermatologists that know the technology, but rarely actually use it directly.

- Current solutions cannot empower dermatologists to be productive enough. This inefficiency is exemplified by the waste of two qualified people for a task that with traditional methods could be executed by a single person.
- The key factor to reach the target population coverage is reducing the average visit time, thus boosting the throughput of the facilities.
- Being mainly large institutions, they can afford considerable investments.
- In particular, they are eager to experiment a novel solutions if it can provide means to enlarge patients intake
- Most public institutions are linked with University, and host dedicated research departments. It is important to them to be the first in line to cutting-edge technology
- Means of demonstrating clinical results in a graphical, immediate, effective way would be an advantage for research, internal evaluation, and presentations in conferences
- The prestige of the institution is paramount
- Particular attention should be given to legal aspects, as the fame of the institution should never be posed at risk.

Users

Attitudes and aptitudes

- Dermatologists are always on the move: between offices, between buildings, between consulting rooms across the city.
- Dermatologists live a hectic professional life. Working days are long and stressful, as the rhythms for visit schedules are prohibiting, and the level of performance required has to keep as high as humanly possible.
- They accept openly the possibility of committing errors, of being undecided about a diagnosis, of being proven wrong by histology results.
- They are, on the other side, self-confident and determined in assessing the most apt prescription, given the margin of doubt.
- They are elastic in experimenting with new techniques, even if tend to be suspicious about relying on them

- They are at ease with the condition of dealing with partial or ambiguous information

- They are proud of being experts. A hint of vanity can be perceived in their use of technological gadgets.

- They overstate their own ability to deal with tight deadlines.

- The interviewers had the impression that the dichotomy of being always in a hurry, but having as a main task that of looking, tended to make them feel not being sufficiently gratified

- They are substantially suspicious of the patient, as the patient can not abide to prescriptions, conceal relevant information or even sue them.

- Still, dermatologists put great effort in trying to make the patient feel at ease, as the latter has to stay at least partially naked for the great part of the visit.

- Their interaction with the patient tends to be detached and strictly professional; much attention is posed in making sure that all and only the necessary information is communicated.

Daily practice

- Most dermatologists have their own standards for taking full body photographs, that actually differ considerably.

- In all cases, the reference for addressing a lesion is a section of a limb or of the torso. As with current technology taking photographs is often time-consuming, such a subdivision is not respected in the subdivision of the body into areas corresponding to full body photographs.

- To approach the collective and serial inspection of multiple naevi, they first look for the bigger ones, and successively explore the surrounding area.

- The visit is performed most of the time standing besides the patient, who is laying on the doctor's couch. The only moments when the dermatologist is seated is at the beginning of the visit, and when he composes the report.

- Sense of responsibility and balance is the only metric for judging when to excise a dubious lesion. Quoting from the attended conference, "Let's not be taleban about it".

- In reality, dermatologists rarely take notes besides what must be written in the patient's and visit report. This is because they have no place to archive them, and they require precious time and attention.

- Making the patient undress is time consuming, especially when dealing with older patients.

- From the point of view of dermatologists the process required by current digital dermatoscopes is far too complicated for the benefits it provides.

- In particular, what if felt encumbering is the inability to move easily the hardware around the patients, of in other rooms.

- Dermatologists would look forward for a more efficient workflow - yet they need be able to focus on uncommon but not-so-rare details. A rigid predetermined step-by-step set of instructions to take photographs in sequence is considered a good solution for a streamlined operation.

Context

- The regulations, common practices, and modes of operation of current technological tools annoy dermatologists with needless bureaucracy, predefined form completion, secondary information as internal database IDs that are as a matter of fact meaningless and useless to them.

- There is confusion regarding the distributing information at the end of the visit, whether it is allowed, and in which format.

Field observation

- Galileo, the patient electronic health reporting system that has been adopted as a regional standard centralised database in public health, is particularly slow, and far from being intuitive. Its use is therefore limited to that of a repository of visit reports, mostly scanned from hard copies.

- To mend for the lack of usable functionality of Galileo, most departments are currently relying on do-it-yourself electronic health report tools.

- Rooms where visits are performed are typically not very large, the size of the competitor FotoFinder obstructs operations.

- The competitor FotoFinder is often not used for online video playback, but for just taking full body and dermatoscopic photographs once the patient has already been screened. The reason might be that it is inconvenient to have to turn around to look at the screen while pointing the "pistol-camera" at the patient.
- The use of the immersion liquid makes it difficult for the dermatologists to switch from one tool to the other, to type at the computer, and to interact with the patient.
- The common shortcoming of analog dermatoscope is that the dermatologist has to bend and put his eye near the instrument, which is in contact with the patient's skin.
- A lot of time is required to perform comparison of the patient's skin and reference images by eye alone.
- As it is requested, during the visit, that patients change position to expose all skin surface to the analysis, old patients are problematic - still they represent a significant portion of the population at risk.
- All interviewed dermatologists had smartphones, in particular iPhones. They are therefore comfortable with touch interfaces and gestures and metaphors proper of the mobile operating systems.

Information acquired via literature review and competitive audits has been already presented in the introductory chapter.

3.1.2 Interpretation

Raw data interpretation underlines many emergent behaviours. Provided the current formulation, it is often easy to detect the underlying goal that originates such bearings. Nevertheless, information gets fuzzier approaching several key aspects. This fact might be due to a an absence of a univocal mental model for such processes. This would mean that there is not a shared attribution of value and significance for the tasks and data involved. The cause could be that digital dermatoscopy is still a relatively new field and its best practices are still not established.

In the first place, there are some recurrent patterns that lead to design imperatives. First and foremost, the new device must be usable and intuitive. Additionally, time accuracy must be matched with a streamlined process and powerful but standardized navigation. Another imperative would be to embed wireless connectivity in the device.

Still, many differences in views ask for compromise in implementing a solution. These debates cannot be untangled by just giving credit to one side, as all current practices are legitimate, and optimal in different contexts. What has to be done is to give support for all such practices, possibly trying to individuate a common substructure that could be applicable by a subset of the parties.

As an example, the order and importance given to tasks needed to perform whole body mapping differs from user to user. Some dermatologists would prefer to take a photograph of the body part, and be able to zoom in on it on a high resolution display. Others prefer to just have a rapid look at it with naked eye and to move on to assessing single lesions. In some occasions others just check up the evolution of lesions in follow up. It is not possible to exclude any of these procedures, as it would comport conferring excessive rigidity to the system.

Some other aspects, though, cannot be compromised to come to an effective solution. An extension of the user mental model must be built anew to fill the gaps where there is no pre-existing one, or where the existing one is ridden by misconceptions. The risk would otherwise be that of keeping the user wandering in a *forêt de symboles*, whose correspondences are taken from different reference systems, that is, partial mental models. However, establishing a new reference system can be done effectively only if it is built upon the users' goals. This way it is possible to maintain coherence with existing partial models.

An example of this situation is which subdivision to choose to capture the human body into full body photographs. A single new standard has to be defined, in order to ease communication and data mobility. Supporting more than one standard would lead to increased confusion.

Another important question is that of the relevance of history in full body and dermatoscopic image comparison. From the collected information it seems that it is recommended by theory, but that in practice it is rarely employed. The lack of a predisposition for incremental comparison is thought to be a result of the low usability of current systems. There is evidence that supports the theory that most dermatologists understate the importance of historical comparison because they were never able to easily take a new photograph in sufficiently high quality and compare it side-by-side, aided by automated difference highlighting.

The same consideration can be applied to the fact that often the only historic full body photograph taken into consideration is the oldest one available, if at all. While it is true that full body photographs are physiologically slow-changing in a healthy situation, they are not in pathologic ones, as is the case with nodular melanomas. Moreover, studies report that 70% of all melanomas are de novo [8, 30].

Expert users suggested the employment of a rigid set of instructions for taking photographs in sequence. They do not feel being able to cope with exceptional cases as a necessity, even if they are not rare. This is because their model does not conceive a digital dermatoscope as a device for interaction with the patient during the whole visit, but just for photo reporting in a later stage. The contrast of this model with their goals is evident, and might be as well due to the lack of usability of the current systems.

Further possibilities are not reckoned because of the insufficiency of current implementations. A large video surface which can be used to interact naturally would the best option to prevent the demerits of the analog and current digital dermatoscopes. A touch interface permits direct manipulation of data, without the need to kneel to reach the dermatoscope eyepiece, and without having to interrupt workflow to turn and switch to the computer's mouse and keyboard.

Not being able to retrieve data easily might as well be the cause of the low direct employment of statistics. Several segments of the population are considerably more at risk of developing melanoma, and there are particular body regions commonly involved within the particular segment.

Another matter of discordance is the polarized versus non-polarized diatribe. The argument is undecidable with the currently available information. There is no clear proof of the absolute superiority of one of the options. It has been demonstrated that each technology has its own advantages in highlighting image features, thus aiding diagnosis for particular diseases. Yet it would be against the requirements of portability, ease of use and low maintenance (among the others) to provide a screw-on lens kit. Moreover, immersion oil has been proven to be much of a hassle to deal with.

Other kinds of situations require to take a firm decision and filter out possibilities that are secondary to the goals of users or are unacceptable by their common beliefs.

One relevant case point is that of automated diagnosis, which is unanimously rejected. In reality, many studies prove that machine learning algorithms can be robustly employed for the diagnosis of several diseases [42]. Moreover, features taken into consideration by the widespread ABCDE diagnostic rule can be detected by a computer. All the same, automatic diagnosis is still perceived as a menace to the authority of the physician.

The considerations presented above are not in contrast with the precepts of goal-driven design, as it may appear. In fact, it is a common misunderstanding that user-centered development must before all abide and conform to what the user is used to, or what he thinks is the best solution to his problems. While it is true that the user must be able to work his way through the interface in the most natural way, limiting to counterfeit well-known products would castrate innovation in favor of cheap instant gratification, instead of empowering the user to ultimately reach his goals.

High-efficency interfaces, as the one mole mapper needs, are an incontrovertible illustration of this argument. Users will make use of the interface for long months, during whole working days. As users will be constantly visualizing and employing the interface, focusing on lowering as much as possible the initial learning curve would have little impact in the long run. In the end, it would result in limiting access to functionalities that would instead permit higher productivity.

The information provided by users is not a literal design mandate. Most of the times users do not have the abstraction skill to pose themselves in a context that is too different from the one they currently live into. Therefore, instead of bluntly implementing user wishes, the aim of innovative design is that of extracting evidence of users goals and technological opportunities, and combining them in an unprecedented solution.

The ambition of goal-driven design is that of proposing a usable concretization of user goals. Its consistent behaviour will provide quick and natural access for the most relevant features. Its responsibility is not that of amazing the user, but to bring to the surface the full potential of the human-technology combination.

The data acquired often cannot be transliterated into a checklist of requirements directly. In order to provide a metric of coherence with the complex and nuanced set of extracted goals, it is often a more powerful approach that of creating several models of the processes involved, of the users, and of the internal data structure that must be represented. This method provides a global reference that enables a natural and complete check of compliance of design decisions with views and goals.

3.2 Workflow model

Seamless workflow is the first characteristic of an highly efficent application. Rigorously modeling such procedures lays a base on which to build interface operations. It is therefore possible to rely on it to test the viability of the interaction design. [7]

From the data gathered from the users and subject matter experts, it is possible to individuate several patterns in approaching the tasks involved in mole mapping and skin condition assessment. As discussed previously, most of the organization of such workflows differs from person to person, yet the basic subdivision into tasks is common. Starting from the technical goals extracted from the data, and using them to evaluate the currently adopted workflows, it is possible to determine the procedures that are most likely to let users reach their targets, and all the same be time-efficient.

A preliminary step is though that of defining a common vocabulary for referring univoquely to such tasks. This is meant as an internal vocabulary, that will be limited to decompose the workflow patterns. Such a choice is useful to enforce the revision of the vocabulary in accordance to user conventions when defining the actions presented inside the interface.

The sub-tasks identified are informally defined as follows.

Anagraphics To handle the basic information about the patient, such as his date of birth or residence. Anagraphic information rarely changes with time. The underlying goal is that of correctly identify the patient at the glimpse of an eye, and to make the patient feel comfortable showing to remember him personally.

Patient report To handle additional information about the patient, regarding his health condition. Such information might comprehend anamnesis, familiarity with particular diseases, examination results, previous visit reports. Data in the patient report is slowly but constantly changing, and is updated with a frequency comparable to that of subsequent visits (months or years as a temporal quantum). The underlying goal is that of not to overlook critical information that could affect diagnosis, and that if forgotten could result in a filed lawsuit.

Portrait To take full body photographs of segments of limb and torso, as with regular photography techniques. This is done in such a way that it eases comparison with future and previous versions of the same body part. The underlying goal is that of having a clear and easy to explore navigational tool.

Mark To individuate and label a lesion within the full body photograph as suspicious, to permit to locate it for further analysis. A lesion might be marked also for reference, even if it appears healthy. All diagnoses and characterisations should be referred to a marked lesion. This means that all lesions that have been taken into consideration during the current visit, and those from previous visits whose status has not been considered normal, should be considered as marked. The underlying goal is that of being able to quickly locate lesions, as they are addressed mostly indicating their position on the skin, instead of their visual characteristics.

Dermatoscopic To take photographs of a single lesion with the aid of a digital dermatoscope. The underlying goal is that of analysing the lesions in ways that would be impossible with the naked eye, and to apply the specialist knowledge. On one side this is a gratifying task, as it requires expert skills, and leads patients to feel the authority of the dermatologist; on the other hand, it is performed mechanically.

Annotation To qualify a single lesion with additional characteristics. Distinguishment could be nominal and/or quantitative, and multiple ranges might be used. For example, the features employed on the ABCDE, EFG, or 7-point checklists may be used, as well as free-form notes or predefined tags. The underlying goal is that of having a rapid overview of the features of lesions, possibly assessed on known valid scales, to be more confident in performing the diagnosis.

Diagnosis to determine the diagnosis for a single lesion, and to establish the corresponding prescription. Prescription should be corresponding to the status of the lesion, and be kept within the options: to excise, to keep in follow-up, ok, excised. The underlying goal is that of being sure to eliminate all threats to the health of the patients, and in second instance to minimize unneeded excisions. It is a stressful task, as it requires total focus, and it determines in the end the aftermath of the visit.

Visit report to enter information in the summary of the visit. The summary should be exportable into different formats, as deliverables might be given to the patient as well as the surgeon, as well as stored in the database internal to the healthcare structure. It should be identified with information taken from the anagraphics, and contain diagnoses and relevant annotations taken during the visit. The underlying goal is that of proving of having done an adequate, incontestable job.

Dependencies in between tasks seem stricter than they are in reality. The visit report follows diagnosis, which follows annotation, which follows marking. Yet, it should be possible to update the diagnosis of a lesion assessed in previous visits without undergoing the complete process (e.g. when the visit is a check up for a recently excised lesion). Moreover, some dermatologists with years of experience in reality determine the diagnosis before looking at the dermatoscopic photograph, while others are strictly bound to the analog dermatoscope: in these situations determining the diagnosis could precede dermatoscopics. Annotation are often useful, but might be skipped, and more importantly they might be updated after gaining an overview on the general type of lesions present on the patient. Marking should typically follow portraits, but there are exceptional cases where it is not possible - it is the case when the patient does not allow to take photographs of his face, or when the lesion is in a position that cannot be covered by standard portraits. Portraits, in turn, should be assessed only after checking the anamnesis of the patient, but in particular cases it is not viable or favorable. There is currently no strict preference on whether to assess a single lesion from marking to diagnosis, or to reach up to an intermediate step for all lesions within a portrait, or within the whole body, before having the final word on the diagnosis.

The most common workflow should follow the sequence anagraphics, patient report, portraits, marks, dermatoscopics, annotations, diagnosis, visit report. The configurations change mainly based on how instances of dermatoscopics and instances of portraits are nested, and whether annotations and/or diagnoses directly follow marks.

Eliminating those configurations that are suboptimal in respect to the proposed goals, and after a confrontation with users, six possible workflows remain. As patient anagraphics and patient report always precede the visit, and the visit report is always present after all other tasks, they are omitted.

The workflows have been divided into two categories. The discerning factor is that the second three are advantageous only if switching from regular to dermatoscopic photography is sufficiently easy, in example if there is a dedicated camera for dermatoscopy, or if the dermatologist can rapidly snap-in the polarised lens. As the mole mapper will be developed preferably on a single device, namely a tablet, it is obligatory to make such a switch as smooth as possible. The development team is contemplating engineering a rail, or a similar appliance, to ease the passage. However, the expandability of the platform makes taking into consideration both alternatives necessary; moreover, the use of an external device could introduce parallelization to a certain

1	2	3
`for each portrait`	`for each portrait`	`for each portrait`
`portrait`	`portrait`	`portrait`
`for each portrait`	`for each suspicious lesion`	`for each suspicious lesion`
`for each suspicious lesion`	`mark`	`mark`
`mark`	`annotation`	`for each portrait`
`for each portrait`	`diagnosis`	`for each marked lesion`
`for each marked lesion`	`for each portrait`	`dermatoscopic`
`dermatoscopic`	`for each marked lesion`	`for each portrait`
`for each portrait`	`dermatoscopic`	`for each marked lesion`
`for each marked lesion`		`annotation`
`annotation`		`diagnosis`
`diagnosis`		

Table 3.1: Workflow models where the switch from portrait photography to dermatoscopy is complicated

4	5	6
`for each portrait`	`for each portrait`	`for each portrait`
`portrait`	`portrait`	`portrait`
`for each portrait`	`for each suspicious lesion`	`for each suspicious lesion`
`for each suspicious lesion`	`mark`	`mark`
`mark`	`dermatoscopic`	`for each portrait`
`dermatoscopic`	`annotation`	`for each marked lesion`
`for each portrait`	`diagnosis`	`annotate`
`for each marked lesion`		`dermatoscopic`
`annotation`		`for each portrait`
`diagnosis`		`for each marked lesion`
		`diagnosis`

Table 3.2: Workflow models where the switch from portrait photography to dermatoscopy is easy

ex tent.

The proposed workflows are reported briefly below, in tables 3.1 and 3.2.

The use of the second profile, even if it conforms to current practices, is discouraged, and will not be included to determine the primary action paths in mole mapper. This comes from the fact that the ability to take dermatoscopic photographs rapidly, be it from integrated or external cameras, is the purpose of the project - and developing it on the possibility of dermatologists relying on hand dermatoscope would be preposterous. It has though been reported for completeness, as if it its support could be obtained with little modification from the other workflows, it would be a plus.

Workflow models are not usually the base for goal-directed design, as they tend to focus on tasks more than user models. In fact, the workflows that will be supported in the end will actually be determined based on personas, a user modelling tool which will be introduced in the next section. Nonetheless, workflows are still an essential tool, that will be used as a foundation to make sure that current practices and the intrinsic technical goals of the tasks are respected later on in the design process.

3.3 Personas

Personas are a powerful model that is able to capture user's goals, lives and environments. Qualitative research poses the challenge of synthesizing in a meaningful manner information that comes from a variety of individuals. The design needs, in order to be effective, precise indications on which are goals that must be satisfied. At the same time, all users interviewed are slightly different from each other, and every one of them most likely has motivations and idiosyncrasies that are not exactly replicated in any of the others. All in all, what must be reflected into the design are behaviours and goals that are relevant to many but proper to none. Statistical analysis would be inappropriate for capturing more than trends in the population of interviewees. It therefore arises the need for a compelling model that highlights cross-individual emergent patterns and decreases relevance of secondary ones.

The motivation that drives users to use the device come from aspects of their life that might not be immediately apparent. Even limiting to everyday aspects that might influence the user's decision to favor the device, those are complex, multidimensional, interrelated. It is for this reason unfit to flatten such characteristic space into a checklist. Moreover, it would be impractical to drill down such a representation every time a decision must be made.

Personas are a simple tool for bringing to light the archetype of the user. It is a powerful way to render an all-round specification of the user's life in a concise, implicit form, still permitting to reply to precise questions in an unambiguous manner. As such, it represents a holistic model of the fine-grained details that comprise people's lives, and the context the device will be used in.

Personas are synthesized based on real world observations, which can be clearly reconducted to data gathered during the qualitative research phase. They are not the outcome of wishful thinking on the design nor marketing team's part. Strictly tying personas to factual information is the guarantee of compliance with the user's mental model. Personas are synthesized individuals, that reflect the goals and characteristics of the user. The employment of personification is essential to foster empathy for its cognitive and emotional inclinations. It is easy to understand the power of empathy to convey the *kansei* of a person when referring to fictional characters in books and movies. Even though personas are represented as individuals, they in fact refer to groups of users. As such, they're sometimes addressed as composite user archetypes. It is to be noted, however, that they are far from being a stereotype: they rely on observation, while stereotypes are based on bias and assumptions.

The advantages that come from the use of personas are several. First of all, they aid in building consensus during the development phase on who the user is. The margins of misunderstanding known as *elastic user syndrome* are cleared. This way marketing, design and development teams are able to consistently refer to the users using a shared vocabulary. Secondly, personas make for cheap and always available reality-check reference models. Even though repeating over and over interviews be the most accurate solution, it is a difficult and costly approach in terms of time to realize. This is for example the case with mole mapper, where user availability for non-crucial inquiries is extremely limited. Using this method multiple design refinement iterations can be performed on the fly at the whiteboard. A third benefit is that personas funnel various levels of cognitive processes. Donald Norman in Emotional Design individuates three levels of cognitive processes that design addresses: the Visceral, the behavioural and the Reflective. Each of these levels present corresponding categories of goals, which are in order: Experience, End, and Life goals [34, 35]. A design that spans through all three levels is significantly more coherent and compelling.

We started to build personas before undergoing ethnographic research to individuate best interview candidates. The primary step is the formulation of the persona hypothesis, that is, a roughly cut outline of the user based on hypothesized behaviour patterns and demographic data. The original hypothesis was confirmed to be mostly correct; still and little modification was required to arrive to the primary and secondary persona formulations reported below. Research proved that the most significant behavioural variables were: personal drivers; level of experience; aptness to technology; frequency and context of use of the device; level and type of responsibility; price-orientedness; relationship with patients; interest in information completeness as opposed to time efficiency. A mapping of interviewed users on fuzzy continuous scales for each variable permitted to analyse the behavioural clusters within user groups.

The constitution process for a persona is what follows:

1. Identify behavioural variables.
2. Map interview subjects to behavioural variables.
3. Identify significant behaviour patterns.
4. Synthesize characteristics and relevant goals.
5. Check for redundancy and completeness.
6. Expand description of attributes and behaviours.
7. Designate persona types.

The outcome of the procedure is typically the identification of a primary persona, that is the archetype of the user the interface is designed for, and secondary personas, that individuate users whose needs slightly deviate from those of the primary persona, but which can be accommodated without compromising device's ability to serve the primary persona.

3.3.1 Primary persona

The primary persona is the primary target for the design of an interface. The interface would not be satisfying for the primary persona if it had to use a design intended to the secondary personas, while in converse secondary users would be fairly at ease with an interface designed for the primary persona. A single primary persona should be present per interface design.

M.D. Sofia Castiglioni, 52, is charismatic and strong-willed. She is married with a private attorney, and has raised two now independent sons: the older is a student at the Law School of Trento, while the younger is on an internship studying Computer Science in the US. Sofia has been working as a dermatologists in the city's public hospital for many years, and she is confident of her preparation and experience. During her career she had several occasions to collaborate to international projects, and she makes sure she is always up-to-date on the latest findings and technologies. She has been working as a part time lecturer for Pediatric Dermatology in the University she graduated from for some years now, but she sometimes finds herself thinking of quitting, in order to be able to focus completely on her research. The hectic time schedules that she must undergo at the clinic are the norm to her, she is used to manage through her busy daily routines. Yet, she regrets not being able to have lunch with her husband more often. Sofia uses digital dermatoscopes most of the time, but sometimes feels like it is a waste of time, in respect to a good eye and a handheld dermatoscope. Still, she wants to be a model for young apprentices, as she sees the benefits that the use of the new technology can comport in the long run. Her main goals are:

- to remain focused and in control throughout the visit, and all along the working day;

- to feel knowledgeable, and to be recognized as such by her colleagues and the specialization students that help her out during the visits. She wants as well to let the patients know that they are in good hands, so to dissolve their fears.

- to maintain her personal prestige inside the clinic and the scientific community

- not to be bothered with irrelevant requests for information from the devices. The digital dermatoscope model she has is too needy in terms of attention.

- to keep the visit as short as possible; however, it is at least as important to her to still remain accurate and complete when inspecting the patient and filing the visit record.

- to avoid at all cost situations that could be considered at risk, from a legal point of view

3.3.2 Secondary personas

Secondary personas present slightly different points of view and peculiar needs when compared to those of the primary persona. However, accommodating for most of their more diverging requests does not debase the interaction model: it is possible to adjust the design to satisfy their specific requests, while keeping intact the experience for the first persona. As a rule of thumb, if more than three personas are present for a single interface, this might be the sign than the product scope is too wide and it might be needed to reconsider the marketing goals. In the case of mole mapper, two additional personas were found, which are at the borderline for being almost too distant in requirements from the primary one. This is due to the fact that mole mapper is targeting expert, highly specialized users, that have constructed a personal mental model where a common agreement is missing. All in all, the design team accepted the challenge to adapt for their demands, focusing first on the primary persona alone, and then adjusting for the secondary ones. It was kept as an internal rule that of discarding the secondary personas when the changes they required were interfering with the interaction model for the primary persona.

Flavio Zampin is 44, and he is charming and decided. His promising career at the clinic started when he was the best of the class at the School of Medicine, and he gained the esteem from his mentor. He has now a reputation among his colleagues as a brilliant professional, and he is expected to be the worthy successor to his old time teacher. Two years from now Zampin started exerting in a newly built private clinic: he can be found most of the time speeding from one to the other side of the city with his Audi R8, a little vaunt of his. When he is working, he is 100% into it, and won't let anything else distract him. He feels the hours in a day are too few to be able to do all that he would like to. While obtaining certainties in his private life is not his priority at the moment, he is confident things will naturally come with time. He still manages to jog every morning before going to the institute; he often has an amateur tennis match on Saturdays, and he dedicates most evenings to keeping up relationships with his friends. Zampin is disillusioned on many theoretical precepts that he has been taught during his student life. He is convinced that common practices and guidelines are intended to cover all generally possible eventualities, and forasmuch he is eager to skip passages when it is obvious they are not needed. Flavio admits to be a gadget lover: he is aware that technology is conferring him a more professional look, and doesn't see why he shouldn't take advantage from this fact - as long as his hi-tech toys are of pristine quality, and that functionality is provided. Flavio uses his digital dermatoscope whenever he has to perform mole mapping, or for the subsequent check-up visits. He is utterly annoyed by the fact that, with the possibilities of today's technology, his digital dermatoscope is making him continuously wait for tens of seconds in between photographs instead of letting him keep his pace: it is unbelievable! He would not think twice to invest on a device that could boost his efficency instead. His main goals are:

- to demonstrate patients his level of professionality
- to come to the correct diagnosis in as little time as possible
- to speed through visit as he does with his Audi
- to reinforce his reputation of a brilliant, rampant dermatologist
- to move quickly from one office to the other, and have instant access to his patient's data

- not to waste time on bureaucracy and formalities

Ilaria Masi, 36, is a new acquisition at the Department of Dermatology. She is a trustworthy and precise person, and as such it didn't take much time for the people around her to appreciate her skills. Four years have passed since she finished the specialization school, yet she rapidly started gaining experience and working her way up, performing up to twenty visits a day: she is the first doctor to show up at the institute, and the last to leave it in the evening. Because of her reliability she was asked to collaborate with other departments within the city hospital as well. This is making her daily routine even longer, but she knows it is a transitioning phase of her life. However, Sofia wants to be able to have time to dedicate to her soon-to-become family: she is planning on getting married to her long time boyfriend no more than two years from now. Working at different departments discouraged her at first, as she didn't expect the internal regulations and procedures to be so scattered and dishomogeneous. She had to quickly build up her own system of values in order to keep sanity, while learning the internal codes and directions, and relying on her spirit of adaptation for uncovered cases. Sofia knows she is the most frequent user of the digital dermatoscope in the laboratory, and she is always asked for help when in the harder days it is needed to speed up the visits. She knows by heart what buttons to press and what is the best way to get things done fast with the digital dermatoscope at the clinic. Nowadays she feels she could be operating it without even looking. Still, there are many shortcomings in the digital dermatoscopy system at the clinic; she wishes she didn't have to work her way around them all the time, switching from device to device to complete her tasks. Notwithstanding the short time at her disposal though, she wants to make sure that she covers all possible cases regarding the patient's condition, and that she doesn't leave the patient exit the office with ad underrated or wrong diagnosis. Her main goals are:

- not to feel belittled by stubborn technology
- not to have to switch from device to device
- to revise what she has done during the visit
- to feel sure about her diagnoses
- to be considered a valued part of the team at the clinic
- to be able to precisely follow a definite routine for all visits

3.4 Scenarios

Personas are powerful tools for synthesizing models of the users that reflect their goals and attitudes. However, they cannot be used directly to address technical aspects. Scenarios permit problem solving by concretization, that is, to both construct and illustrate design solutions [9, 11].

Scenarios are narratives that are built upon personas as characters. They capture the nonverbal dialogue between the user and the device, and puts interaction into environmental and temporal contexts. The evocative nature of narrative permits scenarios to be used in both the creation and evaluation phases. [23]

Scenarios undergo an iterative process of refinement throughout the evolution of the design. They are brief enough not to distract with minutiae and therefore bias design; all the same they are clear in defining plot points that will constitute the framework for interaction. The ultimate usefulness of scenarios is that of translating user goals into experience and technical requirements. [41]

What follows are the context scenarios, an advanced form of scenario, for all primary and secondary personas.

Sofia Castiglioni

- On her way to her consulting room, Dr. Sofia Castiglioni weaves at the nurse on duty through the door of the common hall; while passing she had met with the corner of the eye the look of one of her patients that already crowd the waiting room. As she lays her bag next to her desk, she scrolls with one hand the list of appointments for the day: it will be another full day, but at least she will be able to carve an hour for lunch.

- As the nurse enters the door of her office announcing the first patient, Sofia opens the patient's personal record, which contains all key informations: his anagraphical and contact data, his anamnesis, and a summary of the past visits, besides the histological results notified directly by the Pathology Department. The patient receives a pleasant surprise when he is welcomed using his first name by the doctor, who seems to be able to remember every detail about him despite the time passed since the last visit. After exchanging the usual courtesies, they discuss about updates: in particular, Sofia shows the patient how the results from the laboratory are reassuring.

- Once the patient is naked and lying on the doctor's couch, Sofia screens rapidly but meticulously the skin surface of the patient, confronting it with the original photograph, portrait after portrait. Coupling the actual skin and the photo happens without effort. As a new naevus appeared just under the right shoulder blade, she immediately takes the photograph for the specific portrait: once the image is registered, the device confirms her discovery, and additionally highlights the growth of another small naevus several centimeters below. This second one, as well as the first, have already been marked as at risk, and added to the list of naevi to be further evaluated.

- Since the lady that was expected for the next appointment shows to be a little embarrassment at the idea of her face being photographhd, Sofia adds a placeholder on the virtual model for the preoccupying lesion that she has on her cheek: she cannot afford to let it slip. The dermatoscopic image doesn't indicate clearly to any particular pathology, but when compared to the other naevi on the patient it stands out as anomalous. As the prevalence of melanoma in that position on the body for individuals the same age and gender as the patient, Sofia leaves it as prescribed to be surgically removed, and annotates rapidly the characteristics of the lesion.

- The patient of 1 p.m. did not show up: Sofia forwards the patient's report to her secretary, so that she can attest the condition of the patient and reschedule the appointment. Considering that now she has some more time on her hands, Sofia takes advantage of it and analyses archive data for her latest research: the statistics that were presented in the review she is reading are not matching her own.

- Last patient for the day: once the patient on his twenties finishes to dress up, Sofia adds the last touch to the visit report before printing it; one copy has already been forwarded to the Department of Surgery, with all indications about the lesion to be excised, and another copy is sent to Pathology, with instructions on what is the most significant portion of the lesion that should be used in the dissection. Sofia is confident that, however it is clearly a case of melanoma, it has been detected early in its evolution, and that therefore it will not have any consequence on the life of the boy.

Flavio Zampin

- Flavio Zampin slips on with the impeccability of habitude his white coat. While revisioning the characteristics of the new products the pharmaceuticals sent him, the device notifies him it is time to get ready for the first visit of the day, that will start in 10 minutes; through the notification he immediately accesses the name of the patient, to the fact that the visit is just a check-up, and to the link to the patient's health report. In the next room, the secretary welcomes affable the clients in the bright and well disposed environment, that seems to anticipate the determination and discipline that appear in the doctor's reputation.

- The first patient is a middle-aged lady whom he prescribed the excision of two probable melanomas, and the follow-up for a suspicious naevus. Albeit the patient forgot to bring one of the histological reports, Dr. Zampin retrieves them from the health report of the lady, in highlight between the updates: he was right, those were in fact two cases of melanoma.

- While the lady tells him about the symptoms she perceived related to the last naevus, Zampin quickly scrolls through the sequence of dermatoscopic images he took in time, as well as the ones uploaded by the patient and automatically inserted in the gallery of the specific naevus - there is evidence of some minor change, but nothing can be labeled as pathological straight away. He marks the ones he thinks to be the most relevant, in order to have an easy comparison.

- Unwilling to make the lady undress in vain, he limits himself to take a new dermatoscopic image of the naevus, starting from the naevus' gallery. The doctor is guided in taking the photograph by the preceding image, which can be seen in overlay in transparency. Once the photo is taken, Zampin immediately recognises some atypical features in the color and texture of the naevus. From the comparison with the preceding images, which is accessible from the current photograph's screen, he visualizes automatically highlighted the areas of expansion of the naevus.

- With the new information at hand, Dr. Zampin is able to refute the commentary he had attached to the naevus on the previous visit, and he can now diagnose with certainty a case of melanoma. Together with the prescription to excise, the device permits to choose the diagnosis from a known set, to annotate features of the lesion, and to add other observations; the annotations from the previous visits are in the meantime safely archived, if it not explicitly requested to update or eliminate them.

- As a precaution, Zampin targets a sample of other naevi in the area surrounding the newly found melanoma. He carefully compares the photographs he took first all together in an overview screen, then envisioning the single shots, skimming the ones that could be interesting. The information that is present on the naevus' screen permits to easily locate on the patient's body.

- Once he is sure that the general situation of the patient is normal, Zampin can say goodbye to the patient, after signing and revising the visit report that has been automatically composed based on his annotations. The follow-up visit is set three months from now.

Ilaria Masi

- Despite her young age, Ilaria Masi acquired, in the years following her specialization, an individual method for executing visits, as well as a prominent lack of inhibition in formulating diagnoses; these skills are the result of all the experience in mole mapping visits that she were assigned at a restless and increasing rate. Once she got into the room that she shared for visit with the head physician for her department, Dr. Masi prepares the tools for the day, wakes up the device, and recalls the configuration associated with her profile, well distinguishable between those of the most frequent users.

- Ilaria carries out the first visit of the morning before being able to take a sip of her ritual tall latte: a patient had been sent to her, without proper booking and as an emergency, by one of her colleagues from the Department of Physiatry. While the nurse on duty takes care of the bureaucracy for registering the unusual visit, the doctor retrieves the report for the patient from the device. This way she learns that the man in his forties, who is sitting in front of her a little scared, in reality had already been visited by another physician of the same clinic nine months before - in the visit report, which is linked to the patient report, her colleague had prescribed a follow up in three months for a naevus, fact that had evidently been procrastinated. It doesn't take her more than a glimpse to the preceding photographs to understand that the patient's condition has been understated. As soon as she takes a portrait of the area new naevi appear in the surroundings of the ones precedently marked; the old naevi are carried to the new photograph in correspondence of the position in the old one by the device.

- During the day the visits come back to the norm. The routine of Dr. Masi procedes in its iterations with precision and efficiency: with the patient recumbent, starting from the head, she takes the portraits for the various sectors in rapid succession and following the predefined order, marking lesions that appear worthy of a second look, as well as some sample naevi - in addition to these, the device proposes the ones it evaluates as suspicious, because newly appeared, modified, or marked in previous visits. If on the particular day Sofia doesn't have the aid of a nurse, before making the patient turn she takes the dermatoscopic photographs for the naevi that have been marked to that point: once the dedicated lens is mounted, the device indicates each time which is the next naevus to target, while the count of naevi still without a photograph is decreased. If instead Sofia does have a helper to support her on that day, she leaves the task to take dermatoscopic photographs, while she completes those of portraits. In the end, she revises the acquired images annotating their features and establishing their diagnosis. The naevi that have been marked, but that are judged as not interesting, are hidden by the device for future visits - however, it will be able to retrieve them from the archive.

- Being a considerate person, Ilaria doesn't forget to write down all the information patients tell them, nor to annotate the contextual information of the visit, as whether the patient is pregnant, or has just returned from holidays.

- Dr. Masi spends her afternoon in another building of the same clinic she works with. Ilaria has access to her configurations through a different device that is part of the second office: the device remembers that in this second office the regulations and standards are a little different, because of even more stringent timeframes for each visit. She also has access to the always up-to-date information about her patients. Once the day is over, Ilaria turns the device off, with a sigh of relief and satisfaction.

Chapter 4

Interaction framework

Requirements define what the device will do, before assessing how it will look, behave and feel. Context scenarios are a the reference narrative that enables designers to question how personas will try to reach their goals using the device in their natural environment. Brainstorming on this paradigm it is possible to extract what are the users' needs in a way that directly corresponds to their motivations, responds to their expectations, and that is coherent with their mental model. The main advantage of this approach is that of distilling such needs prior to define what the technical implementation will be: this permits an unprejudiced analysis of the requirements on one part, on the other it allows to modify technical implementations along the development without affecting the experience of the user.

Requirements establish what information and capabilities are needed for the user to reach his goals. Each requirement is comprised of an object, that is, an element taken from the data model, an action over the object, and a context in which the action takes place. Once the data and functional requirements are described, they are checked for integrity and coherence against the scenarios.

Amongst the requirements that emerged from our scenarios, a shortlist of the most critical in pursuing user goals is the one reported below:

- to compare the current version of a portrait/dermatoscopic image with a previous one, after taking the new photograph.

- to compare the dermatoscopic image of a naevus with a that of a different one from the same visit, after taking the new photograph, or when exploring the portrait the naevi are in.

- to verify the appearance of new naevi from the compared old and new portraits.
- to recapitulate the progress of the visit during all tasks
- to derive the common characteristics for the patient's lesions from the overview of the visit.
- to retrieve patient information from an appointment, or from a phonebook
- to retrieve previous visit information from an appointment, or from an agenda
- to start a new visit from the patient's report, from the phonebook or from the appointment
- to move around and select the portraits from an overview of the body
- to receive news and updates for the patient's condition, and to access them from the patient's health report
- to receive a summary for the patient's anagraphics right into the patient's electronric record.
- to access statistics for a particular naevus right from the naevus itself and from the patient's health report.
- to standardize the subdivision in portraits in the body overview
- to be able to take the new photograph of a portrait/naevus with the previous one as reference, to ease further comparison
- to automatically formulate a visit report that is complete and non-ambiguous, right from the diagnosis
- to be notified of upcoming visits when idle
- to print an output report for surgeons, pathologists and patients from the visit overview

This methodology allows to retrieve through brainstorming and verification on the user and context models to bring out undercover requirements in an informal way. It is useful in discovering a formalization of necessities that are not directly derivable from the the list of goals of personas. Even if not all the possibilities that come up in this phase will necessarily be reflected into the interface, others are typically nearer to the real user needs than the more apparent ones. However, this approach tends to be prone to inaccuracy, and to leave much of the framework to be defined from implicit extension of the set of rules. It is important instead to have an extensive outlook on what is the list of requirements. Forasmuch, the requirements individuated were expanded using a different approach, that draws from software engineering, that systematically assesses what the data for the information model is, and what are the functions that are referred to them.

4.1 Data model

For a higher level of completeness, and to permit a more structural overview, the functional and context requirements can be inferred from data requirements. Data requirements are objects and information that must be represented in the system. Each datum is moreover often characterized with various labels that define its status or behaviour.

In the case of mole mapper, the main data comprises of: doctor profile, patient profile, naevus, portraits, dermatoscopic image, health patient record, appointment, visit. The items have been individuated starting from the three scenarios: their interrelationship has been redefined in different iterations, where the final form seems to be more robust and ostensible.

- *doctors*: as mole mapper targets mainly institutions, it is important to provide multi-user functionality. Digital dermatoscopes are felt as less goods of the healthcare institutions, while regular dermatoscopes are thought of as personal. Mole mapper will permit to personalize user profiles, and highlight the most frequent users, in order to create a stronger bond with the device. However, every doctor that is in the list of employees of the institution, and that has granted access to the CiS platform, will be able to pick up one random mole mapper and retrieve his personal configuration. Moreover, finer access control for other kind of medical personnel is required.
- *patients*: Patient profiles are comprised of the anagraphics for the patient, and are implied by the collection of their health and visit reports. Forasmuch, mole mapper will retrieve and adapt patient profiles that are preexistent in the organization.
- *health report*: Patient health reports have to comply with preexisting standards in the organization for archival, but they will present rich and highly contextualized

data, as updates of results from the laboratories, or the successful upload of new dermatoscopic photographs on the patient's behalf. An expanded version will show all fields, while a condensed one will focus on identifying the patient and providing updated content as a priority.

- *naevus*: the naevus is the lesion on the patient's body that is examined by the doctor. Diagnosis, prognosis and historical galleries are referred to the naevus, but are in fact reachable from its instantiation in each visit, that are dermatoscopic images.

- *portraits*: portraits are photographs of segments of the skin of the patient. They are updated visit by visit. Taking a portrait photograph is eased by the presence of the outline of the preceding image, when available, of the virtual human body model, otherwise.

- *dermatoscopic image*: The same considerations as with portraits apply.

- *appointment*: Appointments are part of the agenda, and enable the dermatologist to be active on the visit in as little time as possible. The agenda needs to show evidently how busy the day is, how complicated are the patients that will be treated, and at what point of the routine the doctor is.

- *visit*: a visit is most of the times a concretization of an appointment; however, it might happen that patients show up in emergency conditions without having had the time to do procedures for booking.

- *visit record*: the visit record allows to have an overview of the deicision taken

Decisions regarding how specific or broad to make an entity is delicate. A model that presents generalizations might lose the ability to clearly reflect the scope of action of the user, while one that is too detailed will induct complexities and visual overheads in the realization. The final choice has been obtained after modifying an ER diagram (figure 4.1) in order to obtain no more than four levels of hierarchy, while retaining intact the entities that were the focus of user's goals.

Mapping requirement data to a concise relational diagram is one of the most powerful ways to obtain a global vision of the mental model of the user. The schema allows to understand immediately what data is central, what is a container, what is hierarchically more prominent. Moreover, the use of cardinalities allows to understand what passages in the data flow might be interrupted and need to be bypassed.

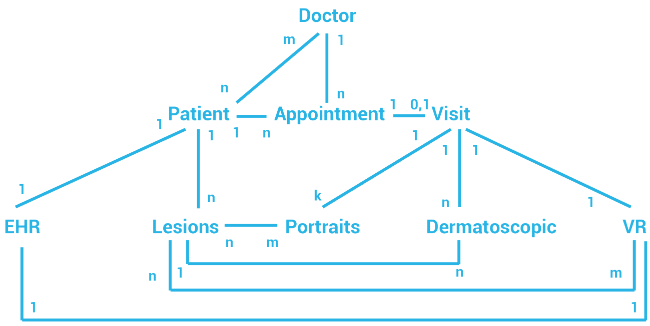

Figure 4.1: Relational diagram of the Data Model

This approach, borrowed from software engineering, differentiates itself from the standard practices in goal-directed design. However, as it will be discussed later on, the interface of mole mapper needs to rely for the most part in navigation through data. Such a diagram will be used as a key element in constructing consistent navigation.

4.2 Action model

Once defined what are the data types and their relationships, the next step is that of listing in an extensive way what are the actions that they will be involved in. This is done starting from the data model, mapping the requirements individuated through brainstorming, and expanding the functional model following the relations in the diagram. What follows is a compact list of the functional requirements to the data defined earlier.

- *doctor*: users need to log in and out of their profiles; for the log in, it is needed that the user is able to search for his profile; profiles can be added and removed from the system

- *patient*: patients need to be added to and removed from the system from medical personnel that has access rights; they need to be searched by name and other non necessarily univoque attributes.

- *patient report*: the patient report needs to be compressed into a summary, and expanded to have access to finer grained details; it must be possible to modify it;

it needs to be refreshed in order to receive updates in real time.

- *naevus*: it needs to be marked in the portrait, and unmarked if judged as not interesting; it needs to be diagnosed; its status needs to be resumed in an overview.

- *dermatoscopic photograph*: it must be possible to explore the skin of the patient to discover interesting lesions; it must be possible to take and retake dermatoscopic photographs, and they must be guided by a previous reference for maximizing similarity in the versioning gallery;it must be possible to eliminate the photograph; the user needs to compare the new photograph with a previous version, and with another photograph from the visit; the user must as well be able to compare all photographs of the visit in one time; photographs can be searched for in the visit overview and offline for statistical purposes; dermatoscopic photographs need to be annotated; in case of comparison with a preceding version of the image, the expansion areas of the newer lesion must be highlighted.

- *portrait*: portraits must be easily accessed from a body overview; some custom portraits might need to be added to the standard collection, for lesions that are in particularly uncommon positions; they must be explored and zoomed in to show details; the user must be able to take and retake the photograph, guided by a reference outline; the user must be able to remove a photograph; a portrait must be compared side-by-side with a previous version from the history gallery, and in this context the appearance of new lesions must be evidenced.

- *visit report*: the patient report needs to be compressed into a summary; it must be possible to modify it in small detail; the user has to be able to easily export and print a copy for patients and other medical personnel; visit reports have to be retrieved for future analysis.

- *appointment*: appointments have to be scheduled, rescheduled and cancelled, as well as their details might need to be modified; appointments trigger notifications when their scheduled time gets nearer; the user must be able to gain a complete view of his appointments on a hourly and monthly basis.

- *visit*: the user must be able to control the progress of the visit and check the summary of actions taken up to that point at a glimpse; a new visit must be created when the user makes an appointment start.

Together with the requirements emerged from the brainstorming session, the list defines what are the functional prerequisites for the interface. It can be noted how such a comprehensive model can be directly translated into the language of the interface. Data will be the content that will be represented into the interface, while functions will map into controls.

The conversion into interaction-enabled components is straightforward and will be omitted. However, from the descriptions of requirements it is not possible to understand exactly how the graphical components will be organized, nor what behaviour they will present or encourage. In the next sections said aspects will be covered in detail.

4.3 Views

The first step towards the composition of the interface is the creation of the context for data and functional elements. Context should be intended in its broader sense, as it starts from the physical confines of the hardware platform and ends at the semantic organization of controls. Establishing the context will ultimately influence the interaction framework as a whole.

In order to start arranging components, the designers must know what are the visual estates at their disposal. Platform, screen size, form factor, and input methods are just some of the main factors that drastically influence how the layout is organized. The small screen of a smartphone, for example, limits the amount of information that can be presented at one time, and therefore asks for a finer subdivision of tasks into multiple screens, through which the user navigates back and forth with gestures. On the other hand, a smart TV allows to display much more data at one time, while the typical distance from the user, and the interaction imposed by the remote, require special attention to how selection is presented and performed.

Mole mapper will be realized for Android tablets. In particular, the Asus TF201, codenamed Transformer Prime, it the product that was chosen for prototyping. It is thought to be the most fitting balance point for user and business goals. One feature that differentiates it from the competitors is the presence of a docking station, that extends battery life, and that provides an inbuilt keyboard and touchpad for netbook-like operation. The other features relevant to its suitability to the specific applications are:

- Operating system: Android 4.0 (upgradable)

- Display: 10.1” LED Backlight WXGA 1280x800 display, Super IPS+, 10 finger multitouch support
- CPU: NVIDIA Tegra 3 Quad Core
- Memory: 1GB
- Storage: 32GB
- Camera: 8 MP Rear Camera with Flash, 1.2 MP Front Camera
- Battery: 18 hours pad with dock; 25Wh(pad) + 22Wh(dock) Li-polymer Battery
- Wireless Connectivity: WLAN 802.11 b/g/n@2.4GHz, Bluetooth V2.1+EDR
- Dimensions: 263 x 180.8 x 8.3 mm (19.4mm with dock)

Figure 4.2: Picture of the Asus TF201 “Transformer Prime”, as a stand-alone tablet, and docked to the companion keyboard. Source: *http://www.expansys.it/*

The posture of a design is the primary definition of its behaviour towards the user. The different postures of an interface depend on the attention the user is expected to give the interface, that is, if the user will look at the interface exclusively, and for how much time, during a session of usage, and during the lifespan of the device. Usually posture is defined by one of the three adjectives sovereign, transient and daemonic.

Mole mapper will sport a sovereign posture. In fact, the application will be the only process visible to the user, its use will not be interrupted by other applications, and the user will interact with the interface continuously. Mole mapper will monopolize the user’s attention for long periods of time. From the designer’s point of view, the implications of designing a sovereign interface comprise the fact that target users will be mostly perpetual intermediates and experts. With the term perpetual intermediate it is intended a user that is neither a novice nor an expert, that understands all primary features of the interface, but that does not remember some of the advanced ones: this might be the case when an expert user doesn't use the interface for some time, and then comes back to it, or when a novice spends significant amount of time on a project that makes him boost his knowledge for the device. Sacrificing speed and power in favor of a clumsier but easier-to-learn idiom is out of place in this situation, as is providing only sophisticated power tools. However, as expert users will these need precise and advanced controls, mole mapper will need to include those as well, without compromising on intuitivity and coherence.

The main quantum that has been used in defining the context of a particular set of actions is a "view". The view is not necessarily corresponding to a screen; in fact, for the form factor that has been chosen, screens often host two or more views. This is because of the convenience of displaying, for example, a navigational view together with a view that shows details corresponding to a selection.

A view is a container that corresponds to a clear division of actions based on their semantics. This helps in grouping together elements that share meaning and correspond to a particular category. The user will therefore be able to naturally look for a control he doesn't remember, or a datum that needs to be analysed, in the corresponding view.

Determining visually the position and context of functions, however, is not sufficient for enabling the user to approach the interface in a efficient way. While it helps in making the user learn where elements are mapped on the screen, and what elements interact with others, it does not encourage particular actions. In order to be able to highlight the most important, frequent, significant functions, it will be needed to apply differentiated visual prominence and consistent positioning throughout all views. In addition to that, particularly rapid interaction methods, such as direct manipulation, minimizes the cognitive effort to satisfy end goals.

Grouping must take into consideration replies to the following questions into consideration:

- Which elements need a large amount of video real estate and which do not?

- Which elements are containers for other elements?

- How should containers be arranged to optimize flow?

- Which elements are used together and which aren't?
- In what sequence will a set of related elements be used?
- What interaction patterns and principles apply?
- How do the personas' mental models affect organization?

These issues are a guide for defining the breadth of a particular view. Moreover, they help individuating the particular constraints for data display within a view. Even further, they permit understanding which are the key functions within a view, and how these influence navigation.

The general ambition of the interaction framework is that of minimizing the effort that is needed by the user to reach his goals. The levels of work that can be spared to the user are multiple and qualitatively different, and the efficacy in permitting lean interaction in respect to each can be considered an evaluation metric for the interface. Effective organization within views has been proven to aid addressing all of them to a significant extent. The types of work that can be minimised by efficient element organization are:

- **Cognitive work** - Comprehension of product behaviors, as well as text and organizational structures
- **Memory work** - Recall of product behaviors, command vectors, passwords, names and locations of data objects and controls, and other relationships between objects
- **Visual work** - Figuring out where the eye should start on a screen, finding one object among many, decoding layouts, and differentiating among visually coded interface elements (such as list items with different colours)
- **Physical work** - Keystrokes, mouse movements, gestures (click, drag, double-click), switching between input modes, and number of clicks required to navigate

The process that takes to defining groups to satisfy such requirements is far from being linear. In fact, it is often an iterative process of subsequent refinement. The steps involved in revisioning grouping into views comprise an ideation, a rapid prototyping and a preliminary validation phase [40]. In the ideation phase functional clusters and hierarchy are heuristically proposed. Subsequently, the organization is reflected into rough sketches: the focus at this point is on higher lever containers inside views, more than the small details. Finally, key path scenarios are used for validating the viability of the proposed design; key path scenarios are use-case narratives, typically much shorter than context scenarios, that illustrate the walkthrough of how the user completes the major interaction within the interface.

The final division into views is reported below. Functional elements are associated with the view where the corresponding action is to be triggered. Such elements might be further replicated in different views in order to provide shortcuts in the navigation, but here are presented only the ones necessary in constructing the primary interaction.

Login where the doctor can login, logout, and search his own profile

Control panel doctor profiles can be added and removed by users with administrative rights

Phonebook patients can be added and removed, as well as searched for

Agenda appointments can be scheduled, rescheduled, deleted; the list overview of the appointments of the day is the principal component; visits can be researched via patient name and appointment name

Calendar here lays a calendar overview of future appointments and past visits, where it is possible to understand from the graphics a rough load estimate for each day

Appointment it is comprised of a summary of the patient report, appointment type and time details, and a summary of its reason; it is possible to modify the appointment detail; a new visit is created contextually

Patient report detailed view of the patient report, and summary of the updates happened in between visits; the report can be modified

Portrait overview it allows to navigate the body of the patient to locate portraits; when a custom portrait is needed, it is possible to create a new one

Portrait the portrait is mainly comprised of the full body photograph, which can be explored in detail; it is possible to mark, and unmark lesions; it is possible to access comparison of naevi that are from the same portrait

Portrait camera the portrait camera mode enables user to take and retake a new photograph of the portrait, guided by the outline of a reference previous portrait, or a virtual model of the same; if the photograph is unsatisfactory, it is possible to eliminate it

Portrait comparison it serves to assess side-by-side comparisons between the current version of the portrait, and a previous version of the same area of the body; the appearance of new lesions must be highlighted

Dermatoscopic image it allows to visualize details about a lesion; it gives an overview of the annotations taken during the visit; it enables to modify the attributes of the lesion, and to provide a diagnosis, as well as a prognosis

Dermatoscopic camera the dermatoscopic camera mode enables user to take and retake a dermatoscopic photograph of a lesion, guided by the outline of a reference previous image, or a virtual model of the same; if the photograph is not optimal, as it happens when the naevus crosses the border of the object-glass, it can be eliminated

Dermatoscopic comparison it can be used to assess side-by-side comparison of dermatoscopic images: the current image is fixed, while the other can be changed through a swipe; the second one can be selected either from the history gallery of the same lesion, or from the gallery of the currently assessed portrait, or from the gallery of currently marked naevi; in case of different versions of the same lesion, expansion area is highlighted.

Dermatoscopic overview it permits group-wise overview of important lesions, such as those marked as suspicious during the visit, or those that were prescribed into follow-up from the preceding visits; it allows quick navigation through categories, as well as letting the user understand how much into the visit he has progressed, and how serious the patient condition is, via status indicators on the single lesions

Visit report it permits in detail visit report composition; once the report is finished, it is possible to export or print it

The subdivision into groups (figure 4.3) allows to identify the responsibilities and scopes of each view from an interaction standpoint. However, it comes more and more natural to think visually of each area, as it is mostly defined by the data and controls it represents. For example, the spatial constraint that photographs require to allow clear analysis implicitly define their centrality and dominance in the dermatoscopic image view. The final composition of views inside screens is though not a one on one mapping. While it would be a good way for enforcing coherence inside the interface, and thus helping minimize effectively the cognitive efforts, it would require too much work in terms of screen navigation and in the very end make the user feel lost and without focus. Additionally, a structure with too many levels of hierarchy cannot be memorized easily. Although the screen real estate of the tablet is limited, it still allows to display at the same time more than one view. Introducing compact secondary views next to the principal ones eases seamless transitions from one detail view to the other. It is a common as indispensable expedient if it is preferred not to make the user jump back and forth from a screen to another. Anyhow, it is after all a process that requires attention and experience, as it can irreversibly blemish the framework. In the first place, the risk of introducing a higher number of elements into the screen is that of losing the immediate understanding of the context. Moreover, it is an hazard to clutter the interface with more controls than those immediately necessary in a particular environment. By the same token, compressing a view and making it of secondary relevance comports threats in maintaining recognizability of functionalities.

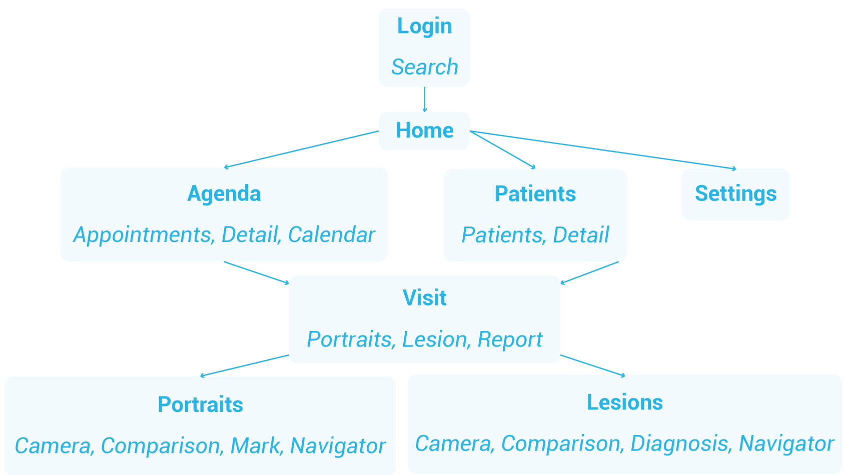

Figure 4.3: The final subdivision of the main views into view groups

Top-level interaction and visual patterns permit to keep a trait d'union between views. As such, they can be used for assembling views in a meaningful way. The next section will explain the process of wireframing and incremental validation that defined the interaction framework.

4.4 Interaction framework

Mobile platforms have gained a central role in everyone's everyday life. Pervasive computing demonstrated to be able to support human activities in ways that were thought not even possible. Their portability together with their connectivity gave birth to socially-enabled services that redefined the concept of Artificial Intelligence. Nevertheless, mobile operating systems and applications are still in the process of finding a stable form. The continuous evolution of the platform induces changes in behaviours and expectations in the user base, which in turn feedback into mutations of the software. This osmosis poses a persistent challenge in keeping the pace of the change, and stable guidelines for sound development have yet to emerge. In particular, the mobile development environment is remarkably lacking patterns for high-efficiency applications.

Design patterns, software design patterns included, are the anthological exemplary knowledge that provides proven solutions to general problems [14]. Relying on known patterns on the one hand allows to advance in the design without the need for reinventing the wheel. On the other hand, it provides a reasonable certainty that the design will be understood by the users, as they will most likely have already been exposed to such models before. From the developer's point of view, pattern increase productivity. There is a wide range of prior experience that can be drawn from, as many patterns have emerged with time from the world of desktop and web applications, as well as from more remote fields as industrial design and architecture.

However, patterns are always context-specific, and cannot be applied blindly. The environment in which a pattern is applied, and the other patterns it is used in conjunction with, change drastically the force that is exerted over the pattern tension points. Patterns might therefore be rendered impotent when applied in extraneous contexts.

The context that is currently associated with the mobile world posed a major impediment to importing patterns in the interaction framework for mole mapper. Mobile devices, in the modern meaning of the word, has gained market success thanks to its entertainment applications. Some of the features that have been considered critical success factors in the marketing strategies of current leading manufacturers are screen size, display pixel density, and camera resolution. Multimedia applications are among the most popular apps in nowadays charts.

Entertainment applications have priorities that are in opposition to those of a high-efficiency interface. By their nature, in fact, entertainment it intended to delight senses, and therefore target visceral goals. This fact affects radically how layout and interaction are realized. The patterns that were popularized with entertainment applications rapidly diffused towards the core of the mobile experience [4]. The typical application structure is a hierarchy of views that are built around a single datum, inducing the user to concentrate on one element at a time, in isolation. While novel navigation patterns through same-level pieces of information have successfully been adopted, often the ability to put such information into context is hindered. It is my belief that this is one of the reasons why Android has revised multiple times the operating system's navigation patterns during his evolution.

It is frequent that applications that involve complex tasks fail in synthesizing a concise structure. The fundamental division into multiple entrenched views cannot be applied productively on data models with convoluted hierarchy, as it results in an explosion of the number of screens involved, and navigation is rendered impractical. Therefore, a new set of interaction patterns must be introduced in order to enable high-efficiency interfaces on heterogeneous applications, such as mole mapper.

A significant effort has been invested in order to integrate such novelties into the existing framework in a consistent and cooperating way. This unification has persisted the fundamental design principles for the platform whenever suitable, while making sure to substitute in a coherent way the guidelines needed substitution. An explanation of the endorsed principles ported from the native android design is briefly reported in the continuation of the section, followed by the newly introduced guidelines. In the end of the section, the foundational patterns for the interface are explained in detail.

4.4.1 Principles for platform integration

Android provides developers with advanced guides that enable smooth integration of apps with the surrounding ecosystem. Instead of limiting choices where an application could potentially clash with the system's native behaviour, Android accepted the risk and gave developers trust. This way Android took on the platform the responsibility of championing the best design, with the conviction that the applications that will best integrate with the overall experience will be the most successful.

For this reason, alongside with technical documentation, a section of their development site is especially dedicated to design guidelines and best practices. Many of the principles presented under the creative vision directly target making applications visually appealing and easy to learn for novice users. While it is always desirable to have stunning presentation and steeper learning curves, they are not priorities for the users modeled, and they would instead detract the value they could obtain with austere, less distracting graphics and advanced functionality.

However, several other principles were considered fruitful for the goals of mole mapper's personas, and were endorsed as ground rules for integration with the overall experience offered by the platform. In the following paragraphs are resumed the principles imported, as they are originally described in the Android Design Guide [1].

Real objects are more fun than buttons and menus
Allow people to directly touch and manipulate objects in your app. It reduces the cognitive effort needed to perform a task while making it more emotionally satisfying. [18]

Get to know me
Learn peoples' preferences over time. Rather than asking them to make the same choices over and over, place previous choices within easy reach.

Decide for me but let me have the final say
Take your best guess and act rather than asking first. Too many choices and decisions make people unhappy. Just in case you get it wrong, allow for 'undo'.

I should always know where I am
Give people confidence that they know their way around. Make places in your app look distinct and use transitions to show relationships among screens. Provide feedback on tasks in progress.

Never lose my stuff
Save what people took time to create and let them access it from anywhere. Remember settings, personal touches, and creations across phones, tablets, and computers. It makes upgrading the easiest thing in the world.

If it looks the same, it should act the same
Help people discern functional differences by making them visually distinct rather than subtle. Avoid modes, which are places that look similar but act differently on the same input.

Only interrupt me if it's important
Like a good personal assistant, shield people from unimportant minutiae. People want to stay focused, and unless it's critical and time-sensitive, an interruption can be taxing

and frustrating.

Give me tricks that work everywhere
People feel great when they figure things out for themselves. Make your app easier to learn by leveraging visual patterns and muscle memory from other Android apps. For example, the swipe gesture may be a good navigational shortcut.

It's not my fault
Be gentle in how you prompt people to make corrections. They want to feel smart when they use your app. If something goes wrong, give clear recovery instructions but spare them the technical details. If you can fix it behind the scenes, even better.

Make important things fast
Not all actions are equal. Decide what's most important in your app and make it easy to find and fast to use, like the shutter button in a camera, or the pause button in a music player.

It is to be noted that the principles that were discarded were the ones that directly dealt with main screen content, which was per platform vision substantially bound to multimedia and entertainment applications. The focus of the presented principles is instead mainly that of providing alternative approaches to overcome disadvantages intrinsic in mobile touch interfaces, such as awkward input methods and limited screen size [36]. Moreover, they address the transient nature of fragmented views, and propose general attitudes towards interface coherence in order to strengthen the sense of unity and favor continuity of interaction patterns.

Nevertheless, this latter group of principles was too broadly intended, and needed a more specific formulation before becoming useful in practice. Additionally, principles that covered how to relate to central content had to be defined anew, in order to support high-efficiency. The next section explains what application-specific principles were adopted.

4.4.2 Principles for high efficiency

While platform-defined principles could generally be agreed with, and are truly essential in immersing services into their context, their core bond with multimedia and entertainment applications made them unsuitable for high-efficiency applications. For example, the discarded principle "sprinkle encouragement" - break complex tasks into smaller steps that can be easily accomplished - suggests an interaction excise in favor of user gratification. A new set of principles needed to be coded into operative definitions in order to overcome the disregard for expertness. The next paragraphs cover the serviceable principles that have been used as a foundation for the interaction framework.

Limit the number of modes

Modes are different states of software in which input and other controls are mapped to different behaviours. Modes are in general confusing, as they require the user to keep in mind in what state the application is in, and change interaction methods accordingly. Moreover what will be the return state of the application when exiting a mode is most of the times unclear. An example of modal operation is that of the ever-famous text editor vi which presents one mode for inserting text, and a separate mode for entering commands, as well as an additional "ex" mode for issuing more complex commands. Whoever used that program at least once cannot deny a rush of frustration in their first attempts at writing a simple text file. The fact that mobile screen mapping is commonly thought of as a succession of panels that cover each other in overlay can be associated to a predominantly modal behaviour. In elaborated applications such a mechanism makes the user lose track of where he is in the navigational path and what is the context of his actions. Modal behaviour should be limited, if not avoided, whenever possible. When it is needed, provide with clear exit paths and enhance situational awareness of the user.

Balance navigation with screen complexity

As noted in the previous sections, screen real estate in mobile devices greatly impacts application structure and posture. On the one hand, the number of controls that can be presented in a single view must be restrained in order to avoid lessening the accessibility and prominence of the main functions, and therefore to keep interaction to the point. On the other hand, paths through a succession of screens cannot be made too long. One of the most cited papers in cognitive psychology states that short-term memory is limited to an approximate number of seven items, plus or minus two. Carrying a whole context with them, the state of complete views requires much more of a cognitive effort in order to be remembered. [33] Navigation paths should be kept short. Screen hierarchy should be as well kept shallow, heuristically within a depth of five [32]. Avoid overcomplicated views, while granting complete interaction with the data displayed.

Minimize input complexity

Traditional sovereign applications in the desktop environment could benefit from rich input methods: direct manipulation, dialog boxes, keyboard mnemonics, and keyboard accelerator. Touch interfaces instead, while permitting direct manipulation of displayed data, suffer from the absence of localized haptic feedback, and cannot provide the enactive memory mechanisms that make the combination of a physical mouse and keyboard still unsurpassed in precision and speed. With current technology this is a problem that has yet to receive a viable solution. The keyboard layout is a standard that will require breakthrough innovation in order to be uprooted from the habits of the general public. Hands-free operation with text to speech applications is still in a beta-quality stage of development, and is far from being ready to support localized specialized vocabularies. Textual input from the user should be avoided. Suitable defaults should be provided instead. Whenever possible, convert free-form input into a single or multiple selection from a list of predefined items, with the use of switches or spinners. Fetch the most frequent or preferred items as first available choices. Be robust to mistyping.

Think of how the device will be held

Tablet computers are characterised by a form factor that users still struggle to feel comfortable in handling. While when laying on a flat surface the interaction with tablets is a source of instant delight [25], the still is no standard set of gestures that is proven to be satisfactory in the standing position [47]. One-handed operation, in particular, is rendered difficult from the inability to provide a stable balance point for the device with the holding hand [43]. Take advantage of the possibilities of two-handed operation, both in landscape or portrait mode, placing principal functions along the lateral borders, within the reach of the thumbs.

Let the user be inaccurate

In applications as the mole mapper the attention of the user should be equally divided between the screen and the real world, as it is in the interaction of the two environments that the full potential of the device will be expressed [39, 52, 55]. For example, one of the tasks that takes most of the dermatologists' time is observing the patient's skin, and comparing it with previous photographhd versions. Make sure controls are not in the way when the user's focus must be concentrated entirely on the screen content. Be robust to inaccuracy when the user must operate the device while looking away from the screen.

Provide with undo

Users of high-efficiency interface perform complex tasks for long periods of time. It is important to them that each and every effort they made in the creation of content is not accidentally invalidated by an incautious action. Humans make mistakes, more so when their attention is challenged by distractions, stress and tiredness. Knowing that their false moves do not necessarily comport disastrous consequences will make them feel more comfortable. Provide users with undo facilities that behave coherently throughout the interface. Keep discarded data until it is reasonable it is not needed anymore. Be prepared to interrupt, resume, and revert transactions.

Let the interface self-describe

Intuitivity is often confused with simplicity, as in minimal and mono-use. Design guidelines for iOS applications deliberately suggest developers to lower the number of controls to display on screen under their User Experience section [2]. While it is true that using limited scopes of functionality permits the user to understand more comprehensively what is under his eyes, it is not a viable approach for elaborated tasks. In fact, intuitivity can be defined of the ability of the interface to self-describe. In this formulation, it can be seen how intuitivity is in essence an interface's ability to let the user reach his goals without the need of providing explicit explanation on what is presented. As Alex Faaborg concisely put it during his lecture in the context of the Google I/O 2012 conference, there are different strategies to obtain self-describing interfaces that can be used in conjunction[1].

* consistency: use of well-known, system-wide patterns. While relying on known information obviously takes away the burden of learning new patterns, high efficiency interfaces often need an unique visual vocabulary in order to be effective. What's more, the meaning for a symbol in the system-wide context could vary significantly when applied to a particular context, thus leading to additional confusion. This approach will be used with caution.

* affordance: implied physics from visual cues. Enrich visual elements with small details that render spontaneously their interaction abilities.

* natural mapping: directly abstracted layout. It has been proven that if controls are presented in the same configuration of the objects they apply to, the correspondence between the two follows naturally.

[1] https://developers.google.com/events/io/

* direct manipulation: no abstraction, act directly on object. Objects maintain in their virtualized representation the potential to be interacted with in the same way they do in the physical, everyday world.

* metaphor: abstract consistency. When direct manipulation is not available, visual metaphors, as with figures of speech, permit to convey the nature of the control in a powerful and succinct way.

4.5 Patterns

Interaction principles are to be interpreted as general indications on how to realize the actual interface framework. They can be seen as a set of rules for intrinsic validation of the design before moving on to use case and user testing. However, they do not provide developers with concrete building blocks. This section will briefly describe the most relevant patterns that were used to enable high-efficiency through mole mapper's interface.

The tasks that dermatologists have to accomplish during a visit are mainly dishomogeneous, as are the data they manipulate. What is more is that streamlined operation is not always executed in the same exact way, as different factors play a significant role in the shortcuts and deviations that every visit may present. A drastic decision taken was not to focus on tasks, as it is the case for all common applications in the mobile platform, but on action flow.

This resolution was reached after several iterations of requirement analysis and rough sketching. While it is a radical conclusion, that sets aside mole mapper from its context under significant aspects, based on this renewed fundamental pattern the overall solidity of interaction escalated to a new level of internal coherence. External coherence with the surrounding platform will be guaranteed as long as the principles defined in the previous sections are respected.

The adoption of flow instead of task as a central interaction pattern permitted to smoothe the multitude of entry and exit points for each subtask that are inherent to the mental model and common practices of dermatologists. One of the most relevant accomplishments brought by focusing on flow was the ability to cut the height of the hierarchy of compounded views. The principles Limit the number of modes and Balance navigation with screen complexity could be combined effectively via the introduction of continuous navigation, a simulation of the one that is gaining success in the World Wide Web due to the recent introduction of HTML5 and CSS3. Instead of splitting a site into several hyperlinked pages, browsable via a list menu, the operation of drill-down into details is performed visually following a precise direction further in the page, as if the hierarchy had been linearized and disposed on a continuous strip. The circularity of the visit routine, with continuous navigation, met a much more suitable representation. In fact, each visit starts from the selection of an appointment from the agenda and ends with the schedule of the follow up visit. Once into the visit, the doctor starts from analyzing the condition of the patient, which is in turn updated when the visit concludes with the visit report. The process of analysis for portrait and single lesions iterates on taking the photograph, comparing it to historic or alternative reference versions, and the detailed annotation of the characteristics for the captured photographs.

Although introducing a modification at such a primordial level of interaction requires from the user to take a significant leap from his expectations, it is a well defined and easy to learn pattern. The user will spend long hours for several days a week using the device, thus the additional bootstrap effort is negligible. Mastering the new idiom will take the experience of switching view from alienating to immersive. [17,19]

I will refer to the conjunction of circular transversal of continuously linked views with the informal moniker of **circular navigation**. In this pattern, the two-dimensional surface of the tablet is used as a navigation plane, where the gesture of swiping horizontally and vertically is associated with exploring the inhomogeneous data model. [24,29] Exploring horizontally, from left to right, corresponds to the act of drill down into the view composition. Such an operation in fact allows to move deeper into detail of the data model, while permitting a higher degree in the sense of context. The continuity of action flow is reinforced by the presence of synopsis views (figure 4.4). Swiping vertically, instead, corresponds to the navigation through instances of the same data type. In example, this gesture is used to switch between photographs of the same item that are taken in different points in time, or photographs of different items in the same temporal context. While a third axis, the imaginary one that is perpendicular to the tablet surface, could have been exploited with particular gestures such as double tap or pinch open. However, it was preferred not to, as it would have interfered with data manipulation. Vertical swipe has been given priority. Firstly, it avoids destabilizing the tablet in one handed operation. Secondly, it is more consistent with how items are ordered in list menus, which are the most common representation for data collections [44]. In fact, list menus display items that are on the same level in the data model vertically, one on top of each other. The single most used pattern for overview-detail representation is that of two-pane screens, where on the left pane is the navigator, whose selection is displayed on the right pane: in android vertical scrolling is often implemented as an exploration interaction in the navigation element, while swiping is horizontal for the detailed content. Coupling the gesture in both panes allows to use a gear shift metaphor coherently, as if the panes were gears of different diameter that transmit each other rotation.

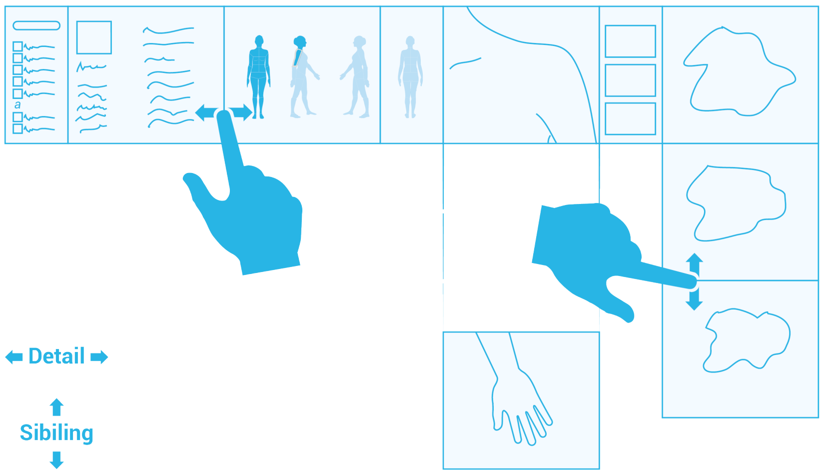

Figure 4.4: Schematics for the circular navigation pattern

Another pattern that was tried to adopt throughout the interface is a standard subdivision of the screen into areas with persistent functions. In particular, the screen has been divided into five main areas. Two thin strips at the top and bottom of the screen are reserved for ever-present toolbars; the rest of the screen is horizontally divided into three spaces, which are in order dedicated to contextual navigation, content, and contextual actions. Contextual navigation has been labeled as such because of its double function of navigating, and expanding the information relative to the content with semantic context. The content portion is further subdivided horizontally, when appropriate, in three sections: overview, detail and description. Description is useful for capturing information that is not strictly apparent from the content image, as tactile impressions relative to a lesion. Note as contextual actions are on the right side of the device, easily reachable in two-handed operation with the thumb of the right hand, leaving the tablet balanced and interacting with minimal physical effort (figure 4.5).

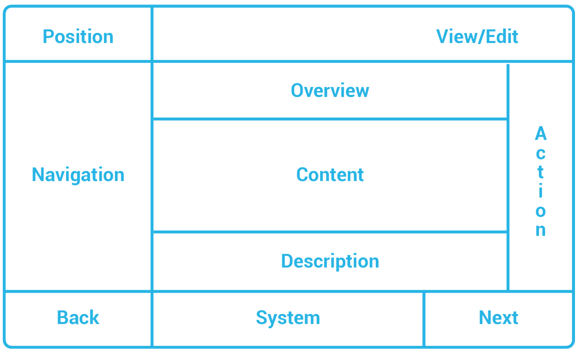

Figure 4.5: Semantic subdivision of the screen area

The toolbars that supervise screen operation absolve to several functions. The bottom toolbar is a visual reference that consolidates navigation, and provides the user with links to the status of the the system. In the first place, a stepping pattern is provided in all screens that derive from the home screen. Stepping is a pattern that allows to progress screens sequentially with the use of a back and a next button. One view is visited at a time, letting the user concentrate on each one. Its linear and incremental progress through screen hierarchy makes this pattern particularly apt to streamline navigation, as the user can touch the "next" button mindlessly to move forward to the next task. Although its behaviour is congruent to the one of the horizontal swipe, the physical presence of the buttons clarifies the affordance, while it provides clear entry and exit points for the current screen. [21] In the case of mole mapper, the buttons are at the extremities of the bottom toolbar, reachable within thumb range in two-handed operation, and are labeled accordingly with the name of the previous or successive view. The combination of stepping with contextual navigation allows to either move orderly through views, or jump to particular items: this freedom of operation is required by real life scenarios, and is the reason why stepping was preferred, as an example, to the breadcrumbs pattern. The center of the toolbar is dedicated to system controls. Here lie the clock, the battery and connectivity status icons, and the data synchronization indicator. Such elements never change in all the internal screens. Time should always be visible by the user, as it is important to him inasmuch a higher rate of visits per day should be increased. The top toolbar instead is tightly related to the current status of the application. On the left side of the top toolbar, in correspondence to the "back" button of the bottom bar, is an indicator of the current position. When the relative affordance is present, it can be used as a toggle for showing and hiding the navigation controls in the content area. The space after the current position is used to switch container views, if more than one container view of different nature is available at one hierarchy level. This is done via a tabbing pattern. The space after the container switches is used for view-specific functions, organised subsequently as view and data controls for the currently displayed content.

As visits require long hours to be executed, and the information handled is complex, the user is typically either concentrated continuously on the screen; yet it is possible that the user leaves the device for significant periods. It is therefore essential to persistently remind the user where he is and what is the current time.

In addition to the presented patterns, colour coding was extensively applied. In particular, the status and diagnosis of single lesions is revealed by colour hinting: red if the lesion is to be excised, yellow if they have to be kept in follow up, green for naevi that are considered normal, black for already excised lesions.

Elements in lists and top to medium level container are always limited in a number that rarely exceeds seven, because of the considerations on short-term memory posed earlier in the chapter.

When dedicated buttons for undo are not suitable, the change in data should be highlighted with a “toast”, that is, a transient, overlay, modest in size notification. Within the context of the toasts it should be possible to revert the notified action.

The selection gesture for content and its representation is a double tap, in order to permit interaction with data with a single touch.

4.6 Sketches and preliminary validation

In order to be able to assess the validity of the current design, it has been found that rough sketches are more effective than pixel-perfect mockups. Pencil and pencil-like drawings, in fact, better promote discourse about design choices, and thus diminish the number of iterations needed to adapt to the required modifications. Low-fidelity presentations permit to overlook the visual aspects that at this point are not strictly necessary, allowing to focus on the interaction framework instead of the graphical detail.

The concretization of the interface, again after iterations of refactoring of information presentation and organization, follows a top-down evolution. The first phase, also called the rectangle phase, concentrates on the entirety of the top-level framework. Its name derives from the rectangles that are used as placeholder for groupings of data and controls. What is most important in this passage is providing meaningful organization, and estimating the real estate allocated to each group. After container objects are laid out, designers can move on to a finer grain of detail. The second phase is that of creating mockups that suggest the form and position of elements inside the containers. The organization is adapted on the way as elements gain more realistic representations. Wireframes are the last step before starting to define the final rendering of objects inside the screen. They still retain the approximations of drawn sketches, while well approximating the dimensions and proportions of the interface elements. It is useful to test whether all primary functions are immediately understandable and reachable.

During all progress through interface refinement, several checks for consistency can be performed to understand which aspects are well rendered and which need refactorings. One such method is paper prototyping.

In the words of Carolyn Snyder [45]: *"Paper prototyping is a variation of usability testing where representative users perform realistic tasks by interacting with a paper version of the interface that is manipulated by a person 'playing computer,' who doesn't explain how the interface is intended to work."* Paper prototypes pose several advantages. First of all, they are cheap both in terms of money and time.They permit to collect user feedback early in the design development process. All in all, the allow to experiment with various idea before committing to one.

Unfortunately, in the case of mole mapper there was no possibility to involve users at this point. However, several methods for in-house use-case simulation can be successfully applied. This way it is possible to limit explicit user feedback to the definitive phases of interface evaluation.

Key path scenarios permit to inquire how a persona will interact with the product. They describe the precise behavior of each major interaction and provide a walkthrough of each major pathway. Key path scenario typically evolve from context scenarios, but address visual elements and make use of the interaction framework's vocabulary.

Another simple but effective preliminary validation medium is short-term amnesia, primarily thought for small development teams that cannot afford to hire a professional designer. What it does is forcing the developer in charge of the design to selectively feign to forget how an interaction element works. The developer then tries to reconstruct the element's behaviour only by its visual cues and relation to the surrounding environment.

Chapter 5

Visual framework

In parallel with the interaction framework, the visual aspects of the interface should start to be considered. The visual language has a great impact on how the user perceives the device, and therefore relates to it on a pre-rational, visceral level. In fact, it is via the visual language that the interface can represent its content in a way that mimics the look-and-feel of real life objects, materials, symbols. The visual framework is the orchestration of the elements that allow the device to appeal and engage the user, let him identify with it, and understand in a more effective way what are the values offered by the interface [50].

However, in this work the visual framework should be considered of secondary relevance. The reason for that is that, especially in a high-efficiency interface, it is the interaction framework that mostly dominates the overall user experience. The expectation for such an interface is that of making the user the most productive, and not to be distracted by beautiful images.

It is not my intention to falsely accredit the notion that visual aspect can be overlooked in order to obtain an effective product. Constructing a detailed visual rendering of the interface requires specific skills, such as that of an industrial designer or digital artist, and a dedicated design team. This document will not present nor discuss the fine details of icon representation, or typeface and font metrics, as it surpasses the scope of interaction design.

Nonetheless, at least some general visual guidelines are fundamental in defining the user experience, and as such will briefly be covered to complement the interaction framework. While form should follow function, as per the famous Modern architecture principle, the experience offered to the user is only one for both the visual and interaction frameworks. As such, form and behaviour should be designed in sympathy with each other.

5.1 Visual language

While choosing the style for the interface, it is important to take into consideration the goals of the users, while maintaining coherence with key aspects of brand and marketing image, and adapting to platform-specific themes and elements.

Mole mapper users are knowledgeable experts that will use the device to consolidate a high profile, prestigious, technologically advanced image with colleagues and patients. The overall look of the device must therefore have a professional, to the point, even spartan appearance. However, it should avoid making the user feel lessened or intimidated by an overly cryptic and cold impression.

Considering that the users will use the device for long hours several days a week, it would be appropriate to let them feel at ease. As such, the view of the interface should be comforting and relaxing, but not so much to flatten the multitude of data and functions that need to be represented. The interface should not hinder the immediate reachability of the advanced features and fine grained controls that dermatologists need in their regular practice.

The image that best embodies the desired values is that of thoughtful helper. The device should be considered above all a smart and reliable support tool. As a considerate assistant, it should provide the relevant information without pretentiously forcing the user to look for them, nor exhibiting in search for unprompted approval.

The look and feel provided by the Android platform is coherent with the one that is sought after for tuning the experience for the mole mapper. The ability to present a consistent and striking appearance that would fulfill said specifications was one of the reasons of the choice of Android. In fact, it provides an ample array of elements that can be used to build a solid base for the application without radical modifications. The "holo dark" theme, in particular, corresponds to most of the visual criteria that will be discussed in the following paragraphs. What is more, the platform permits in-depth customization of the interface components, yet not without effort. Likewise, while the Android design guidelines are rapidly and significantly evolving with time, and sometimes introducing contestable novelties, they are general and elastic enough to permit personalization of the single applications while maintaining unity in the overall system behaviour.

The visual style that is used throughout the interface can be characterised in brief as follows. Most of such decisions have been taken in order to adapt to the visual characteristics of skin, the principal content the interface is revolving around.

Line Lines are barely visible, straight, never marked. This leaves space to the compact fills that compose the elements of the interface without imposing visual rhythms that would impact on the focus on content.

Space The interface overflows the available screen estate, expanding its content on a two-dimensional virtual surface. Semantically coherent fragments are combined in screens that emerge from the porthole of the tablet to slide away as soon as their function is completed. This accentuates the sovereign posture of the interface, while relieving the urge to crowd screens with extensive amounts of controls.

Visual weight The composition of single views is determined by the necessities of data to be represented. As such, visual weight is asymmetric and peculiar to the single combination of views, in order to adapt at best to the content. The constant vignetting of the two toolbars highlight the landscape orientation of the screen, and the relationship between the vertical and horizontal dimensions.

Colour The interface is dominated by dark tints. This enables the content, which is predominantly fair, to pop up and rise from the controls without efforts. Moreover, excessive brightness of colours would become piercing to the sight after hours of use, and when returning to the device after examining the patient's skin with the naked eye. The palette of the interface is prevalently based on shades of grey and desaturated cyan. Although sparingly, bright colours are used to pose evidence to primary content, as well as to label it for immediate interpretation. As an example, lighter shades of red, yellow and green are used for differentiating the triage of lesions, while full-opacity cyan is used to consistently implement selection. All elements are prevalently monochrome, with the exception of solid fills being alternated with block frames to highlight content.

Form The interface is composed of flat, sharply defined rectangles with a tendency towards squareness. This amplification of bidimensionality is necessary in order not to distract from the inherently bidimensional photographs of the skin. Three-dimensional elements would introduce shades that would easily overpower the visual contrast of a naevus from the skin.

Texture Solid, desaturated colours and highly geometrical figures are matched with a compact texture, that makes elements feel as if they were overlays cut from a sheet of paper. Smooth and homogeneous areas are laid out in opaque layers, with occasional translucent superimpositions. Glossiness is avoided, in order to render the feel of a textile, leather-like surface.

Intensity The dense colours and shapes of visual elements provide an immersive experience. The reduced palette, the immediate contrast of focused elements, and the matte texture, however, help the eye to reach significant information without fatiguing the eye even after prolonged usage.

A margin note on iconography should as well be spent before presenting renderings of the screens. Once again, an admonitions should be kept in mind while estimating interaction design from realistic visual prototypes. Symbology and visual language underlying iconography should be developed in parallel with visual designers, as they affect both the appearance and the intuitivity of the elements they represent. As this study is predominantly focusing on the interaction level of the interface from a systemic point of view, in depth considerations on icon metaphors and their representation is out of its scope. The overall style of icons, however, should match that of the system and the visual language chosen. In the case of mole mapper, they must be monochrome, bidimensional silhouettes. They should also not be overly detailed, in order to be able to scale to small sizes without losing their expressivity.

5.2 Screens

Pixel-perfect renderings are essential in imposing the constraints of real world implementation to rectangle-phase drafts. The actual space occupied by interface elements, their resulting visual weight, their respective disturbance in recognizability usually require several iterations of refinement of the design. Moreover, polished mockups are imprescindible to form a realistic impression of the interface: from details affecting the affordance of principal components, to the perception of integration with the chosen platform, the final user experience can be assessed comprehensively only after a high fidelity rendering of the interface. However, realistic illustrations are prone to deviate the dialogue on interaction design towards comments on visual features. High-efficiency user interfaces, in particular, are mostly influenced by information organisation, control disposition, and screen navigation, that are not directly related to choices in visual language. As such, it is important to keep in mind the distinction between interface design as an organic display of data and functions, and its appeal to the eye.

As discussed when formalising interface requirements and dividing them into internally coherent functional groups, views are compounded in order to form screens. With the adoption of circular navigation, the composition is updated to introduce views in a dynamic fashion, either one at a time or in conjunction.

Mole mapper is intended to run in isolation from the rest of the Android environment. Its first incarnation is intended to be a custom installation on tablets dedicated to its sole use. While integration with the system is maintained for future possible aperture to installation from the public marketplace side by side with other applications, it is designed to take over the screen from the very start of the device, taking the place of the launcher, and expanding his area overriding the system bar. The first two levels of view groups, the Login and Home screens, are used ideally only at the start of the working day, and serve as a welcoming step to let the user dive into the interface before actual intensive usage.

From the Home screen, medium tier screen levels provide functionalities for configuration and initiation of action. The Settings view group gathers set-and-forget preferences that allow user to tune the experience in fine detail. The Agenda and Patients view groups are the central entry point for visit management and preliminary information acquisition.

The internal view hierarchy relative to the actual visit administration is condensed into three main centers of interest, one gesture away from each other on the average use case. Key path screens are aggregated into the three levels of Visit, Portraits and Lesions, significantly reducing navigation dispersion. All view aggregators present signposts as a constant affordances for dynamically switching semantic group, as well as for internal view composition, and content navigation. The Visit group consists in an overview for the overall advancement of the visit, consistently providing a resume for the other levels.

It is worth noting that the hierarchy that must be transversed for key paths in interaction is three at most for all presented usage patterns for each visit, while the globally different screens that could be crossed are never more than seven, Login and Home screens included.

In the next paragraphs the peculiarities of each view group will be discussed in fine detail.

Login screen

The function of the Login view group is that of letting the user come at ease with the CiS environment (figure 5.1). As such, personalization and a slight visual excise is permitted in order to favor identification. The welcoming screen is minimal, presenting just a custom login form that reflects the information of the user that handled the device in the middle of the view. The device unit is designed to be used by a single individual throughout the working day, and at most by a limited number of different professionals inside each office. As most of the time the user that will pick up the device and unlock it will be the same, this approach enhances the sense of ownership while resulting in requiring the minimum number of interaction steps, and the least possible user input: the password for the account. No login request button is used, as it would be redundant with the input methods typical of touch interfaces: with virtual or keyboard operation, login submission is done via the enter key.

In the case the user handling the device is not the one presented in the login form, event that is supposed to be infrequent, it is possible for him to reach his profile through the only other visual affordance of the screen, in the top left corner. The position of this element is coherent with that of the contextual overview and navigation elements in the internal levels of the interface. The button toggles the presence of a list of users that are enabled to work with the device. The list is contained in a drawer that slides in from the left side of the screen, in correspondence with the position of the button, making the previous view to slightly compress towards the right (figure 5.2). The user can pick his profile from either an extensive list of enabled users, of from a shortlist of the most frequent ones. As it is likely that the device will be used in a reasonable timespan by one to six people, as it emerged from the preliminary interviews (one to three professionals per office, and typically a dermatologist works in one or two different offices), the shortlist will be capable of displaying all of them so that they are reachable without the need of scrolling. Both the complete and the short lists permit to search for the profile: searching is performed in a powerful way, matching first or second name, and immediately displaying partial results while the user is typing. The

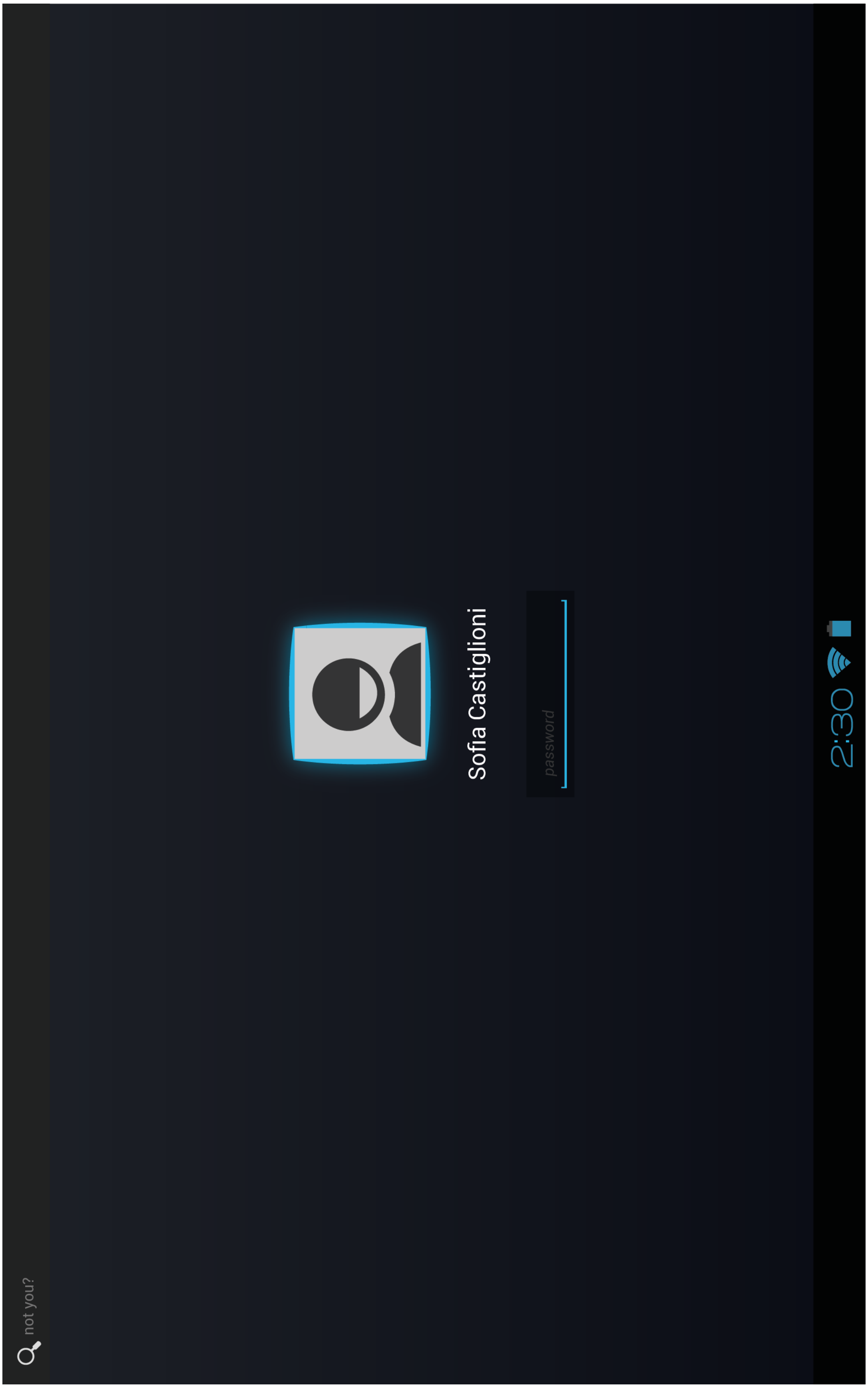

Figure 5.1: Mockup of the view group Login, displaying the main view.

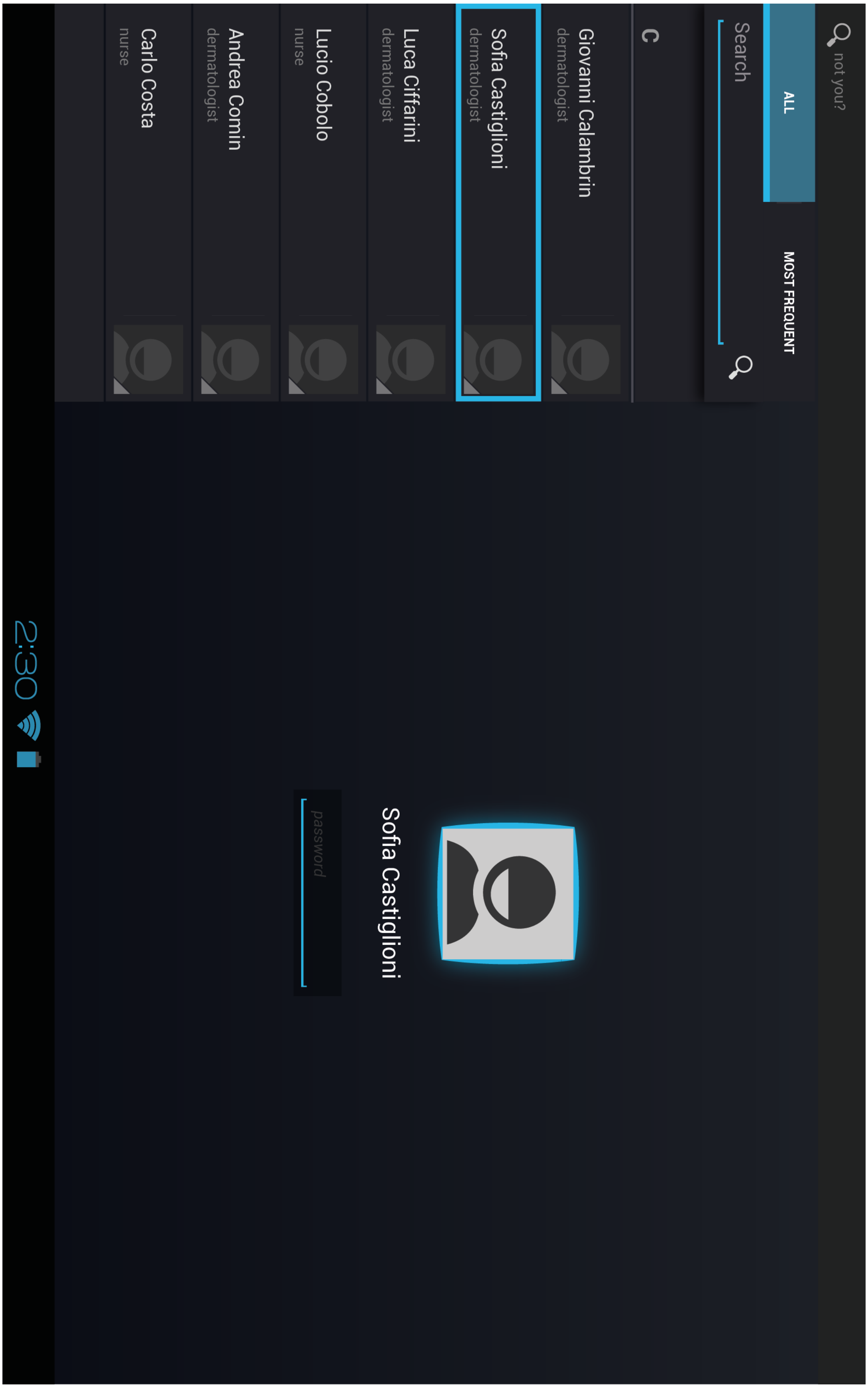

Figure 5.2: Mockup of the view group Login, displaying the user search panel

list items corresponding to profiles are accompanied by the custom user photographs. It is possible to add new users to the list only through the Settings view, as administrative rights must be certified to perform such an operation. This fact, together with the additional information on the role of the users, and the dedicated list for frequent users, are aspects that differentiate the search view from the one in the Patients view group.

The system information will be present from the Login screen on to notify the status of the device, in the center of the bottom toolbar. Such elements will persistently be a reference for the user in all screens. Time is a most valued resource in the hectic working schedules of dermatologists, and as such it should always be kept immediately available. Battery and connectivity grant that the results of the user's work are safely persisted, and as such should be constantly under control.

Home screen

The home screen carries on the minimal visual facets of the login view group, while introducing the interaction patterns that will be used throughout all the internal view groups. The center of the screen is outlined by a horizontal strip, on which are laid out the icons to access the Agenda, Patients, and Settings view groups(figure 5.3). The position inside the view hierarchy is clearly visible on the top bar, while the stepping pattern is established on the lower bar. The back button is associated with the power status button, that permits the user to put the device in power off, or to log out: either way, the view group that will be presented after such operations is coherently that of Login, eventually separated by an unlock screen. The next button is associated with the Agenda view group, as accessing the list of appointments for the day is the preferential way to access the contextual information for a new visit. However, this preference can be changed on a user-profile basis in order to best match the user's own path for visit execution - which, as it was noted during the interview phase, is far from being a commonly accepted standard.

Settings

The Settings screen directly corresponds to the system-defined default appearance. The top and bottom bars, peculiar to the application, maintain their function: the back step button is associated, as it should be intuitive, with the Home screen, while the next step button is disabled (figure 5.4). It is divided in the standard overview-detail split panel in order to permit clear presentation and straightforward interaction. Preferences

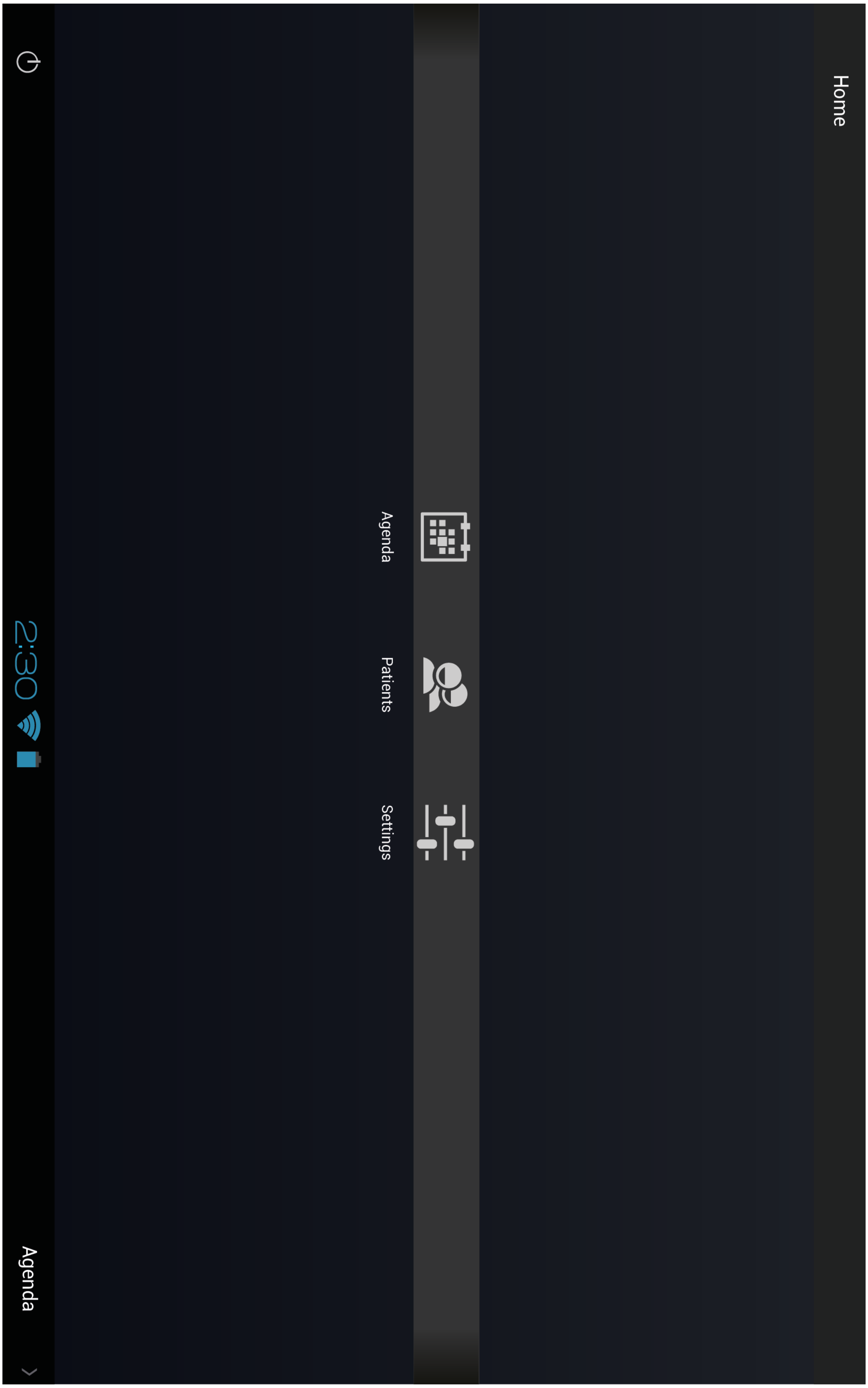

Figure 5.3: Mockup of the Home view

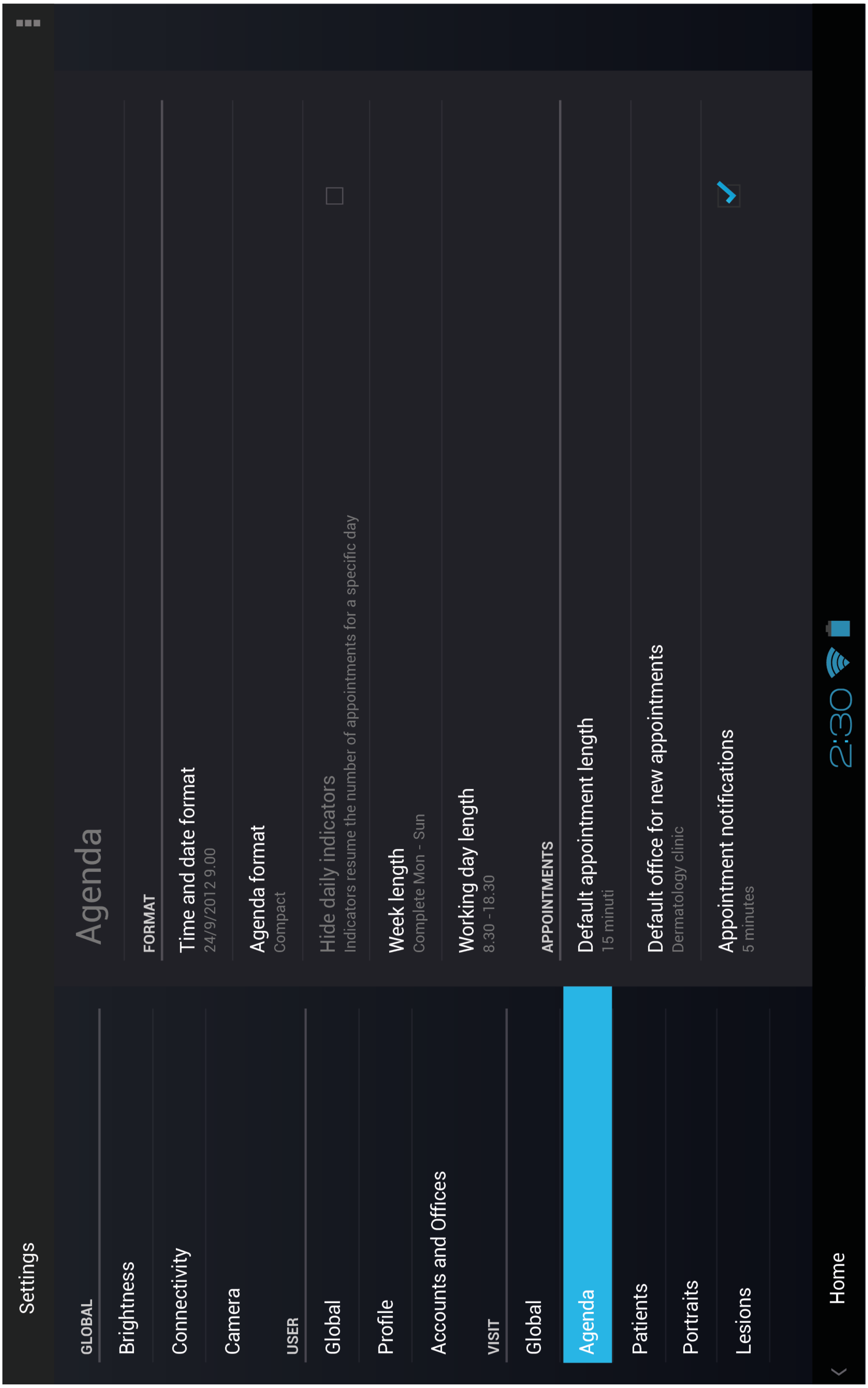

Figure 5.4: Mockup of the Settings view

stored in the Settings screen should need not to be accessed frequently, if at all - the experience is already tuned with reasonable default configurations. Items are grouped following the Android guidelines, divided into sections and organized in subscreens. Group cardinality is contained in order not to break the rule of 7, and at the same time groups with too few elements are clustered in meaningful ways [32]. The general line of conduct that was chosen was that of limiting to one level of subscreens whenever possible.

Patients

The Patients view group permits to access the patients' electronic health reports, and gain complete information over their current and past medical condition. However, the Patients screen does not limit to retrieve the information from the central database and report it plainly. Instead, it tries to highlight the most urgent and novel updates, to facilitate patient identification, and to provide quick access to contact information (figure 5.5). The top bar, besides the position indicator, presents a set of tools to interact and manipulate the visualized data. The elements that comprise this segment are the edit, undo, redo, and delete buttons. Once the edit button is pressed, the content of the main view turns from read-only to modifiable. Patient health reports rarely need to be manually changed, as general anagraphic and contact data are substantially static, and the visit reports and medical history of the patient are automatically enriched and synchronized. Letting read-only operation be the default mode permits users to handle the device without needing to waste attention to not accidentally alter important data. The delete button displays a confirmation dialog to make sure that the user wants to permanently erase the patient's data. Once the delete operation is performed, a toast shows in the center top of the screen to both notify the completion of the transaction and provide an temporarily duplicate the possibility to undo. The stepping elements are consistently pointing back to the Home screen, and forward to a new visit with the patient. The screen is divided horizontally into three sections. The first section is a searchable list of all patients. As with the user profile drawer in the Login view group, whose features are replicated coherently in this view, the search facility is enhanced in order to be robust to mistyping, partial match on name and surname, as well as on key items in the reports. The results of the search filter are refreshed in real time as the user types. On the right side of the search area it is present a button for adding new patients. The new blank entry can be modified acting directly on the interested fields, as the report enters automatically edit mode. The second panel serves as a resume of the latest updates regarding the patient. Below the patient's name and photograph, the overview composes of two sections containing the next appointments, and news

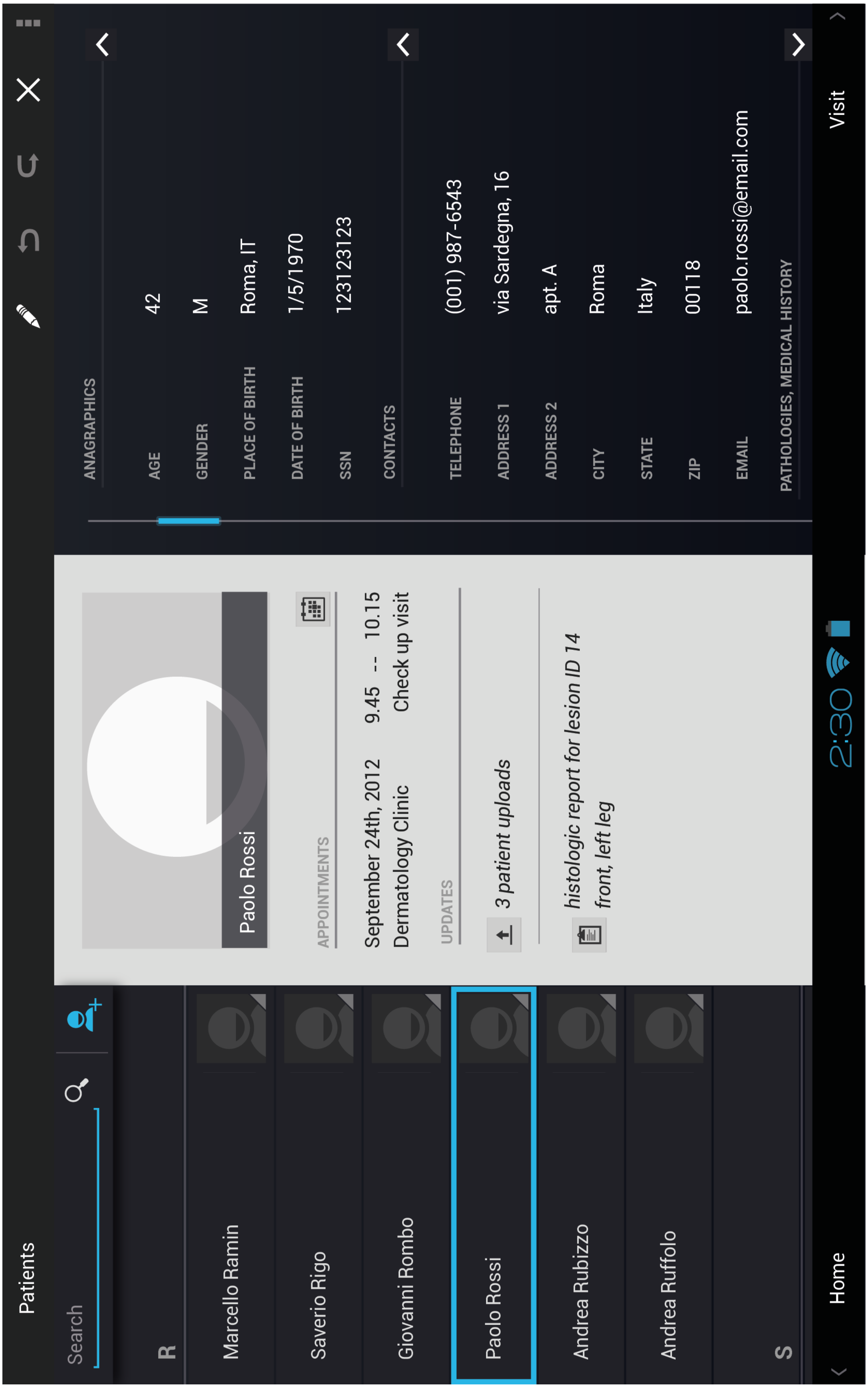

Figure 5.5: Mockup of the view group Patients.

occurred since the last visit - for example, laboratory test results, or image uploads by patients with personal screener. A button next to the appointments section divider permits rapid access to the Agenda relative to the patient. This way the dermatologist can quickly arrange a new check up visit after having considered its necessity with all data at hand. The third panel contains health report information. High priority is given to anagraphic and contact information, in order to permit the user to immediately identify the patient, and reach him if urgent evidence emerges from updates. The health report information is categorized and divided into sections: besides anagraphics and contacts, the other sections cover pathologies and medical history; therapies and drugs used; visits, exams and operations; allergies and vaccinations. Individual sections are collapsable via a toggle button on the right of each section header. This behaviour permits to display extensive information, while enabling rapid comparison of particular entries.

Agenda

The Agenda view group presents itself in an overview-detail split panel (figures 5.6 and 5.7). On the left, similarly to the Patients screen, a list of appointments is automatically prompted to the current date and time. The list consists of two elements, stacked vertically on top of each other. The top layer presents in the first row two view controls affecting the list. The search button permits filtering, coherently to what is present in the rest of the interface. Next to the search button, a second one permits to reset the list to the current date and time. Under the two button the main area of the top layer is occupied by a date picker, in the form of a spinner for days, months and years: controls of different granularity permit to minimize the operations needed to perform even big jumps in time.The spinner is updated with the position in time displayed in the lower layer. The spinner widget is a slightly modified version of the one provided by the system: as the list underneath makes the time flow direction apparent, the next entries in the spinner in both directions can be suppressed as redundant. On the right side is a button to create a new appointment on the date indicated by the spinner. The lower layer consists of the list of booked appointments. Each list item presents the appointment start time, the name of the patient, and the scope of the visit (e.g. mole mapping or check up visit). Next to the scope of the visit there is a graphical representation of lesion condition since the previous visit: the number of lesions that were prescribed for follow up or excision are immediately intelligible. This rendition lets the dermatologists rapidly evaluate the time needed for each visit, and schedule his day accordingly. On the detail panel are presented informations about the appointment, highlighting those that are considered more significant to recapitulate

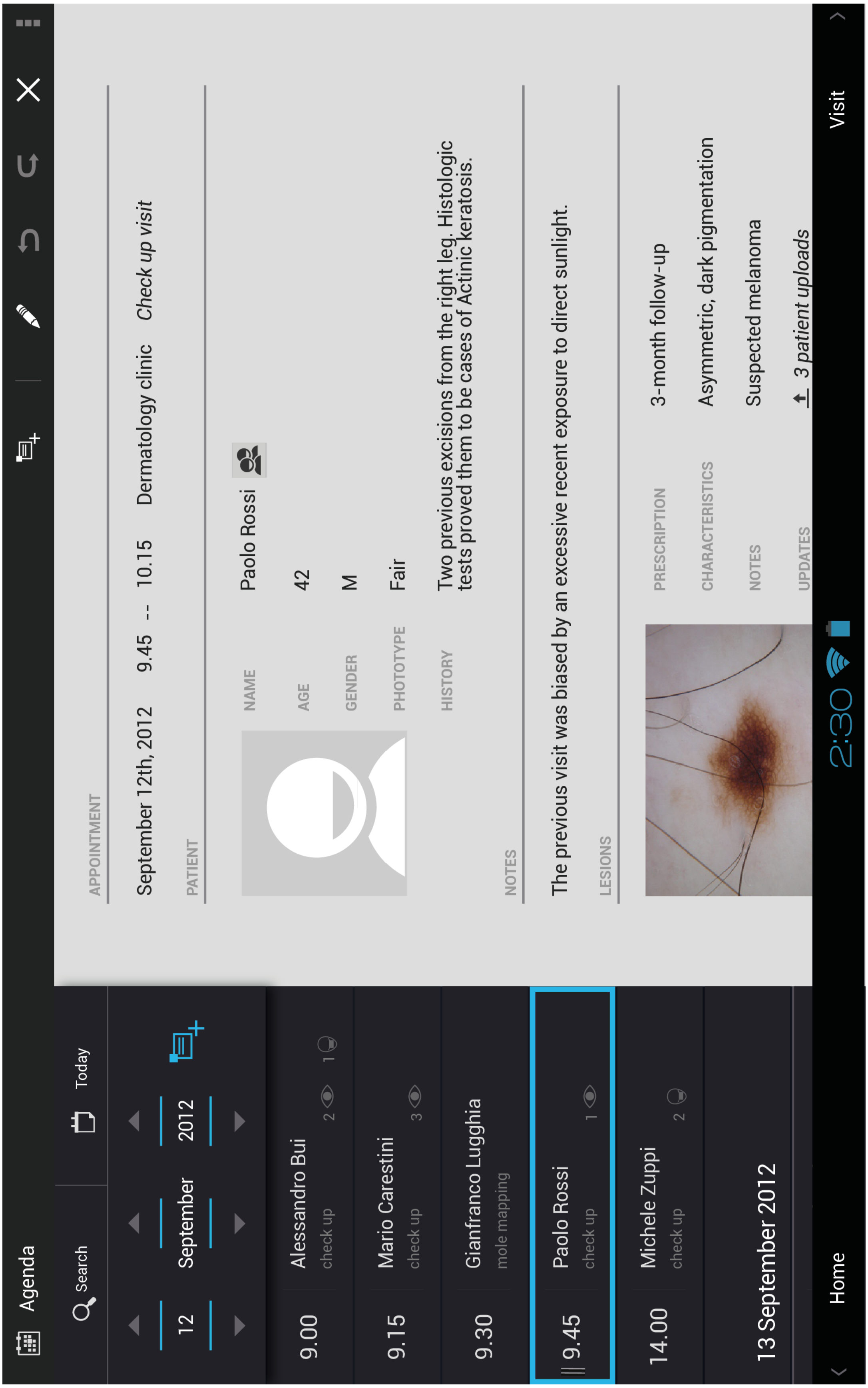

Figure 5.6: Mockup of the view group Agenda, showing its main screen

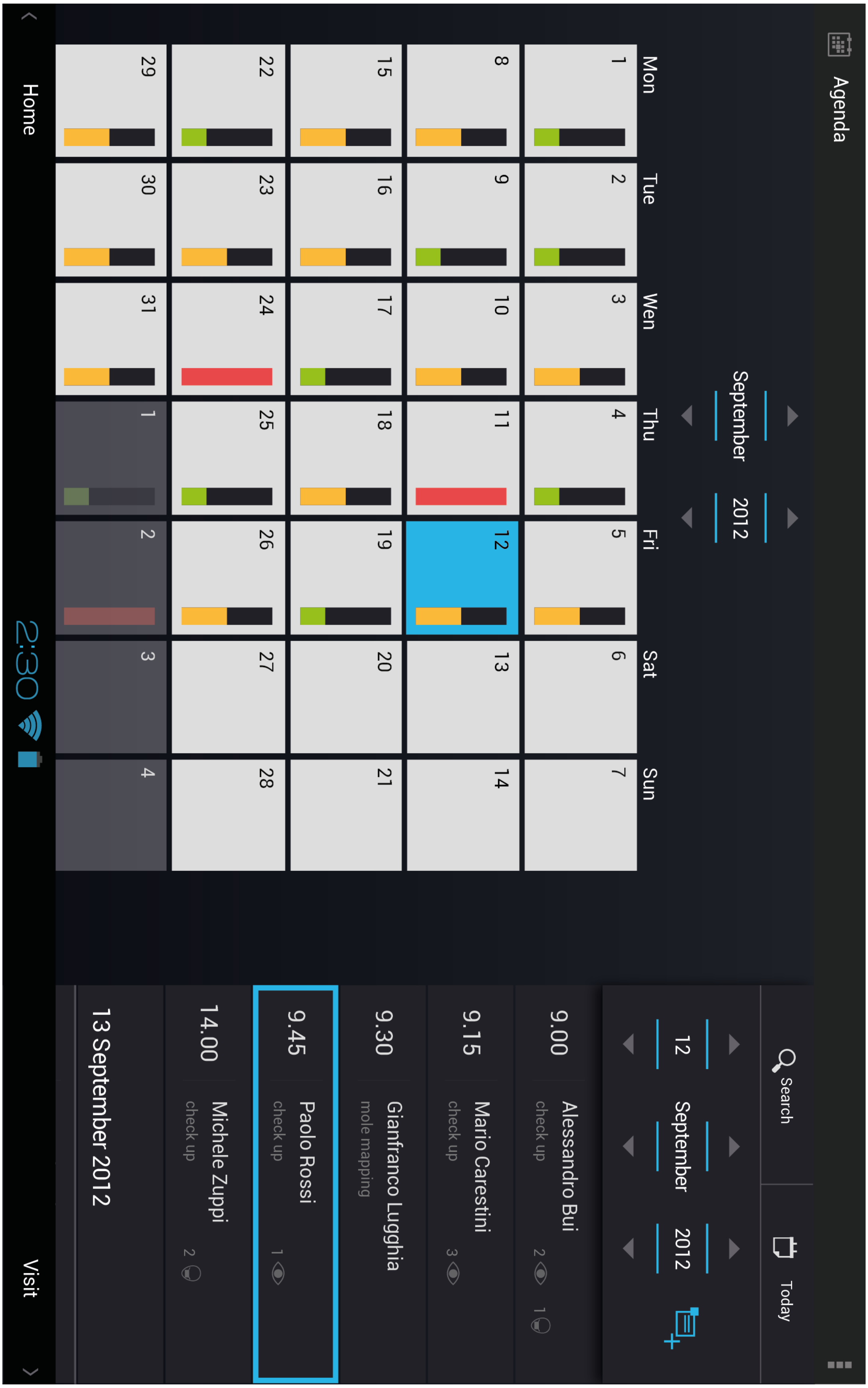

Figure 5.7: Mockup of the view group Agenda, displaying the calendar panel

previous visits. The particulars about appointment time, duration, place and type are communicated first, followed by a digest of the generalities and history of the patient. If the user wants to inspect further, he can directly open the folder of the patient in the Patients screen from a button next to the patient's name. Together with session and patient information, the appointment detail is enriched with the notes taken on the previous visit, as well as lesion information extracted from the previous visit report. This way the physician is able to review the patient's condition at the glimpse of an eye.

The creation of a new appointment is typically performed via the new event button next to the time position spinner. Once the button is pressed, a new appointment is created at the end of the appointed day. The list limits itself to display current appointments, without providing time slotting to preserve readability. However, the selected appointment presents on its left margin an affordance that suggests grabbing. If the user touches and holds the list item, or tries to drag it along the list, the preceding and following list items move apart to make room for fine-grained time slot ticks. The standard length for an appointment, and the quantum for time slotting can be decided in the Settings panel, and are defaulted respectively to 30 and 15 minutes, the median values obtained from the interviews. An alternative way to specify timing as well as other details is using the editing buttons provided in the upper tool bar, which share meaning with those in the Patients screen. The only difference in the tool bar is a duplication of the new appointment button.

Another feature that was introduced to better serve user goals is the presence of a third view for contextual navigation. A template for the ones in the internal level of the interface, the presence of a contextual navigation element is notified by the presence of a clickable icon next to the position element on the top left of the screen. In order to permit a comprehensive overview of the appointment load on a higher scale than that of a day, a calendar view can be recalled as a slide in drawer from the left edge of the screen. The calendar presents a dedicated month and year spinner, and provides a monthly recapitulation of the load for each day using colour-coded bar indicators.

The stepping elements, as with Patients, point to Home and Visit. The double path to reach visits (through both Agenda and Patients) is inaevitable and deeply rooted in the dermatologists' daily practice and mental model. The semantic separation of their scopes, the mutual direct linking of the two view groups, and the closeness of the two through the Home view make the disadvantage not present in real implementation. Moreover, it is expected that a single dermatologist will follow only one of the paths:

as such, the preferred visit access path can be configured in the Settings section.

Visit

The internal, frequently used screens are each divided into three main views, accessed via a tabbed pane embedded in the action bar, right next to the position element. The Visit view group, the first of the three internal levels, is comprised of a portrait, a lesion, and a report overview. The Visit is accessed any time the dermatologist wants to attest the global development of the visit, scrutinizing the items on which he has focused, augmented with contextual information. Thanks to its resuming nature, navigation from the Visit perspective to a particular detail is precise and effortless.

Visit - portrait

The portrait outline is a minimal view that permits to quickly assess body coverage of the patient with full body photographs. At the same time, it allows to locate all marked lesions on the whole skin surface, making it possible to evaluate their distribution. The main elements of the view are a set of four human silhouettes, showing the user alternatively the front, right and left side, and back (figure 5.8). The silhouettes, which match the gender of the patient, are divided into a standard set of portrait areas, following the principles proposed earlier in the section. Portraits that have already been covered are coloured with a bright cyan, while the ones still unexplored present heavily lowered opacity: besides being able to immediately understand which portraits have already been assessed, this approach permits to get a feel of how much the user has advanced into the visit basing on the overall saturation of the screen. The portrait areas can be directly selected to transition into the actual Portrait view. Over the silhouettes are overimposed placeholders for the marked lesions, in the corresponding positions of that on the patient's skin. Lesion placeholder are colour-coded in order to permit their diagnosed status. To underline the progress into the visit, a covered portrait counter and a progress bar are present on the bottom center of the screen.

The top bar provides two buttons to add or remove complementary portrait frames. Such frames can be chosen from a list of known but uncommon ones, like the plant of the feet or the top of the head, or created from scratch. This option is essential, as there will always exist particular shots that cannot be included in a standard set, because of sharp angles forming between the camera and the body part, or extreme infrequency.

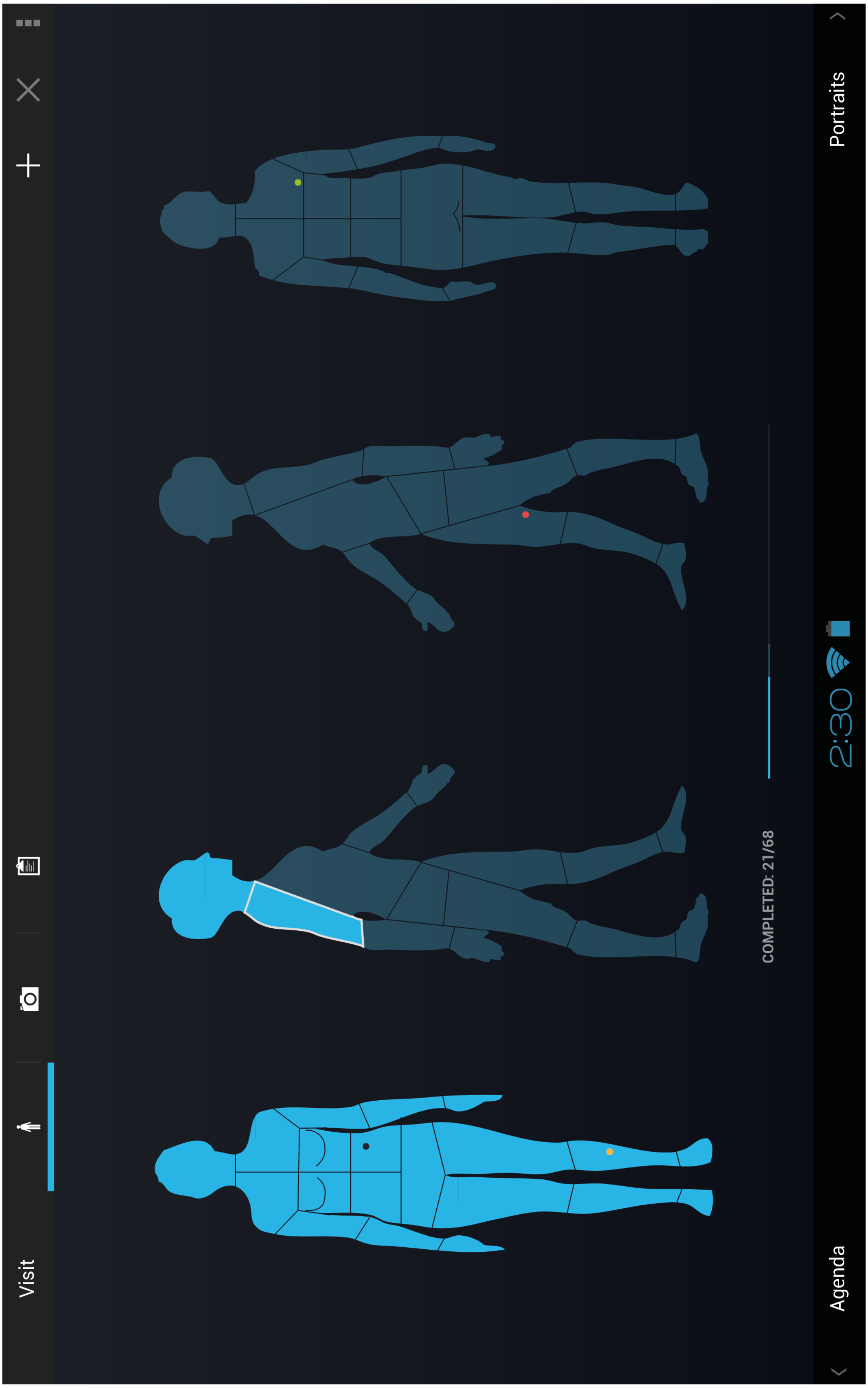

Figure 5.8: Mockup of the view group Visit, displaying the Portrait view.

Visit - lesion

The lesion overview provides a self updating synopsis of lesions marked and photographed during the visit. The user goal that mainly motivates the form chosen for this view is the need to understand which is the typical naevus feature set that is particular to the patient. In fact, the emerging ugly duckling diagnosis rule suggests that a high number of malign lesions is statistically improbable, and that lesions that are most dangerous are those that stand out from the rest, not necessarily because of feature usually related to pathologic conditions (figure 5.9). Up to now dermatologists had to keep track of the visual features of all processed naevi only by memory, or had to iteratively select the individual saved photographs, losing context and not being aided in giving a collective estimation. In order to maximize efficiency of expert eyes, data is presented upfront in a clear way, tagged with identification and location information, colour-coded per diagnosis, and divided into scrollable columns. The area given to photographs is maximized basing on the interview information about average number of lesions of which photographs are taken during the visit, average number of follow up lesions, and typical number of removed lesions. With the given presentation of items lined up vertically side by side it is straightforward to notice when the number of suspect and malign lesions are exceeding that of non pathological naevi. Lesions are divided into four columns: three for healthy, suspicious and to be removed lesions, and one for lesions imported from the previous visit. The latter are automatically distributed into the other columns as well as lesions that need to be checked. The overview provides a snapshot of lesions marked during the visit that is updated in real time. Lesion thumbnails are selectable in order to access directly the dedicated Lesions view. The focused lesion permits easy removal from the list showing a delete affordance on the top right corner.

On the top action bar it is present a button to display the thumbnails juxtaposed uncategorized in a full screen gallery, in order to gain an even better unbiased overview to spot the deviant lesions.

Visit - report

The report of the visit is as well automatically updated with prescriptions of lesions to be removed and checked in subsequent follow up visits. It enhances the traditional visit report including photographs of the lesions and their locations, to communicate in a more powerful way with patients and other professionals involved in the treatment and analysis process. The screen is composed as if it were a single sheet of paper,

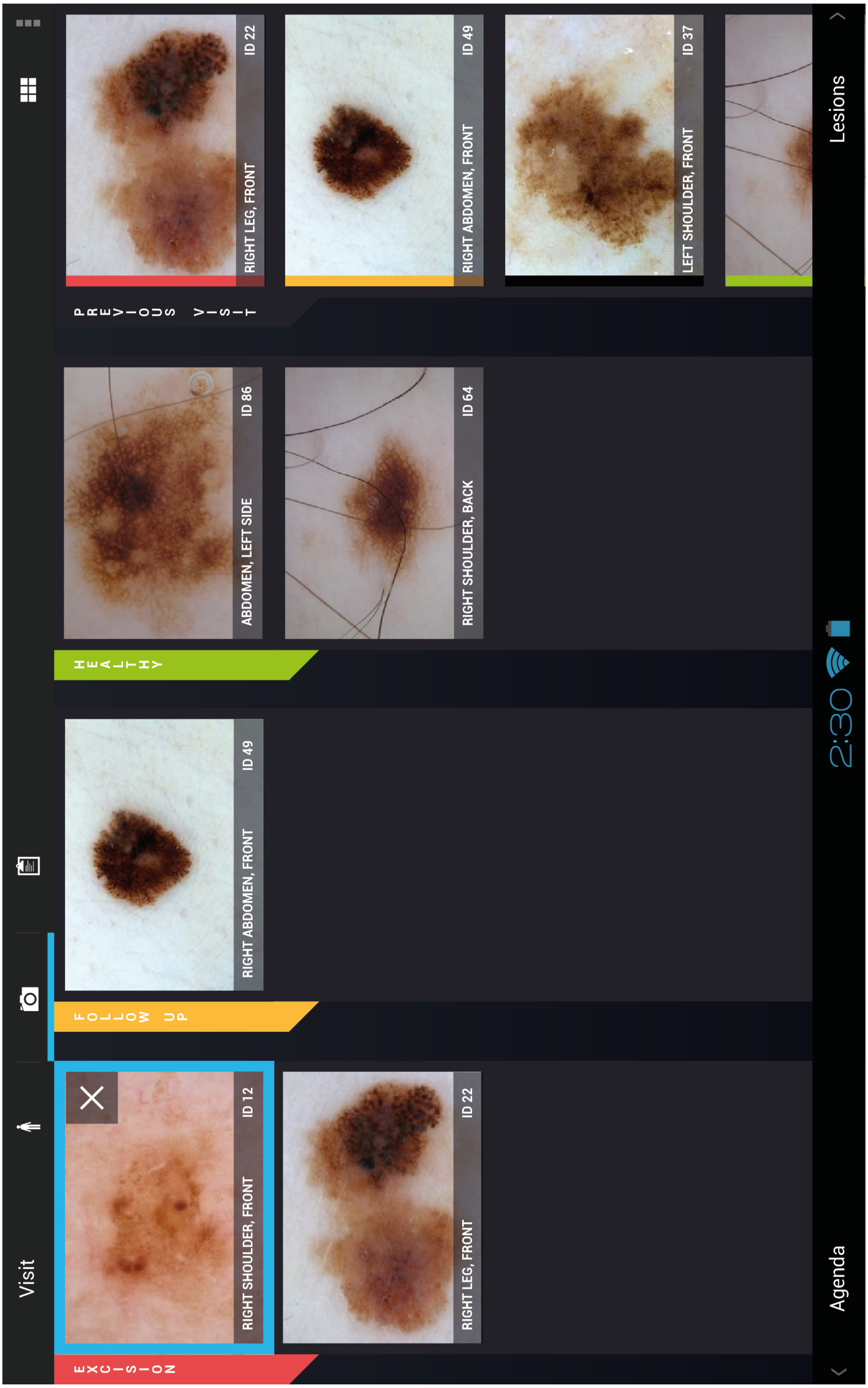

Figure 5.9: Mockup of the view group Visit, displaying the Lesions view

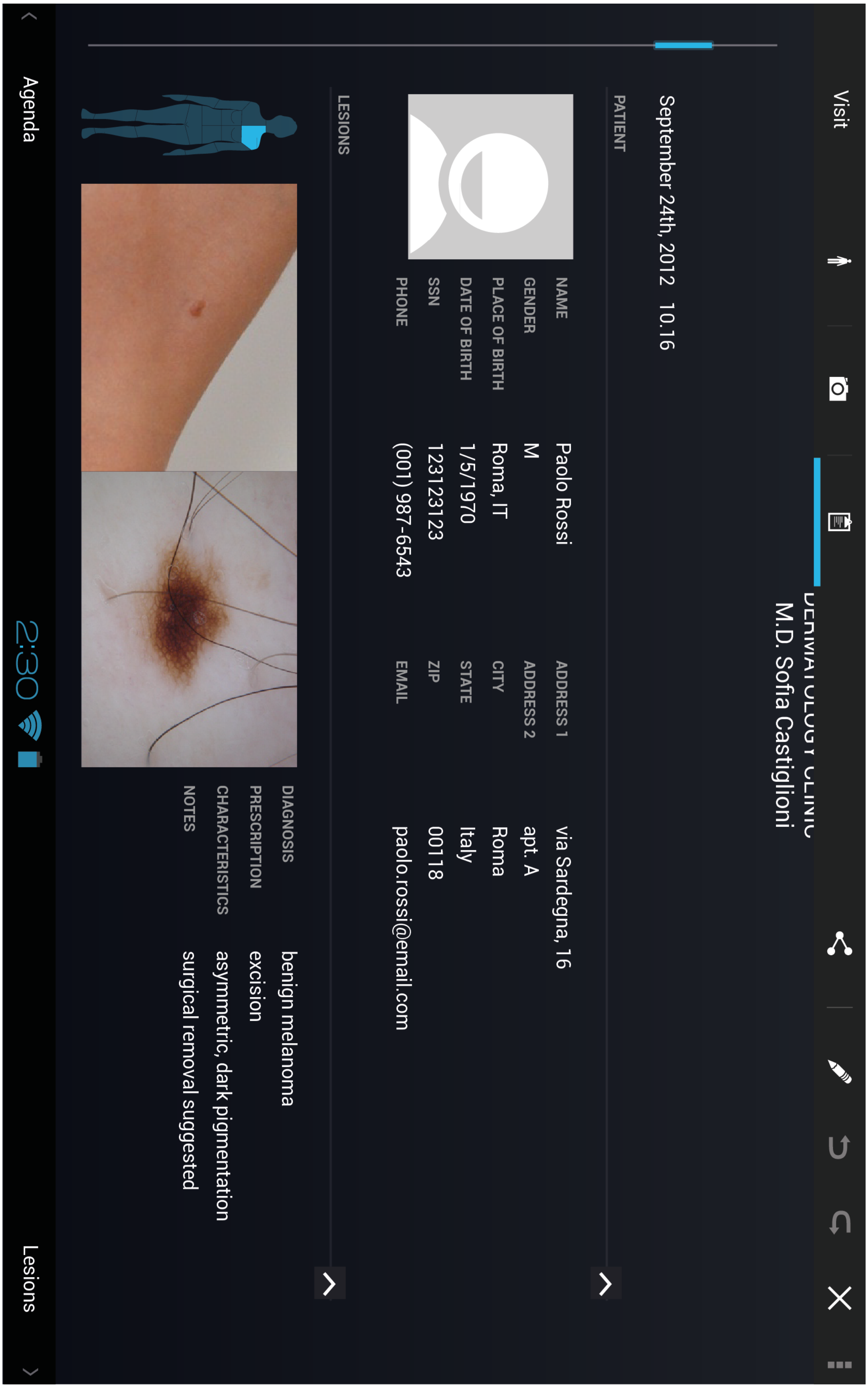

Figure 5.10: Mockup of the view group Visit, displaying the Report view.

providing an automatic print preview. However, to increase readability and capability to confront items, it is divided into collapsable sections - in concordance with the patterns used in the other text-intensive views (figure 5.10). The header of the report can be customized changing content and applying a personal logo. A first section with patient information reflects anagraphical data gathered from the visit report. A successive second section displays lesion information: each lesion is fully located with the highlighting of the relative portrait in the body silhouette, and via a detail automatically extracted from the portrait image. A final section discusses the outcome of the visit following predefined templates and formulas.

The action bar, besides the already presented editing tools, offers a share button, that can be used to send the report to the printer. It could as well be used to directly email the digital report to interested departments and specialists - however, legal aspects tied to patient data usage are still to be clarified.

Portraits

As it was the case with the Visit view group, Portraits are divided into the camera, comparison and mark views. The exit screens associated with the back and next stepping operations are common to all three Portrait views, and are respectively Visit in portrait overview, and Lesions that appear in the portrait. Another common feature of all Portraits is the presence of a navigation element, accessed as per interface pattern via the position element, which is emphasized with a dedicated icon. The navigator consists in the body silhouettes that are part of the Visit portrait overview, which collapse in a tabbed pane once a specific portrait it selected. Tabs are partially hidden in order to minimize the required screen estate, but they can be retrieved both tapping the edges and flicking the silhouette around. The navigator is displayed by default for five seconds, after which it is hidden in order to leave the scene to content. The navigator can be recalled both by the position element and circular navigation, swiping from the left of the screen. It is in fact an insertion of a mid-level view, but as it spares in most of the cases a complete view group change, and as it constitutes a higher level container representation (all in all, a summary of the preceding screen), it is coherent and convenient for the particular aim to high-efficiency.

Portraits - mark

The mark view is dominated by the portrait, which presents on its top edge just a transparent strip in overlay to identify the photograph with a description of the body

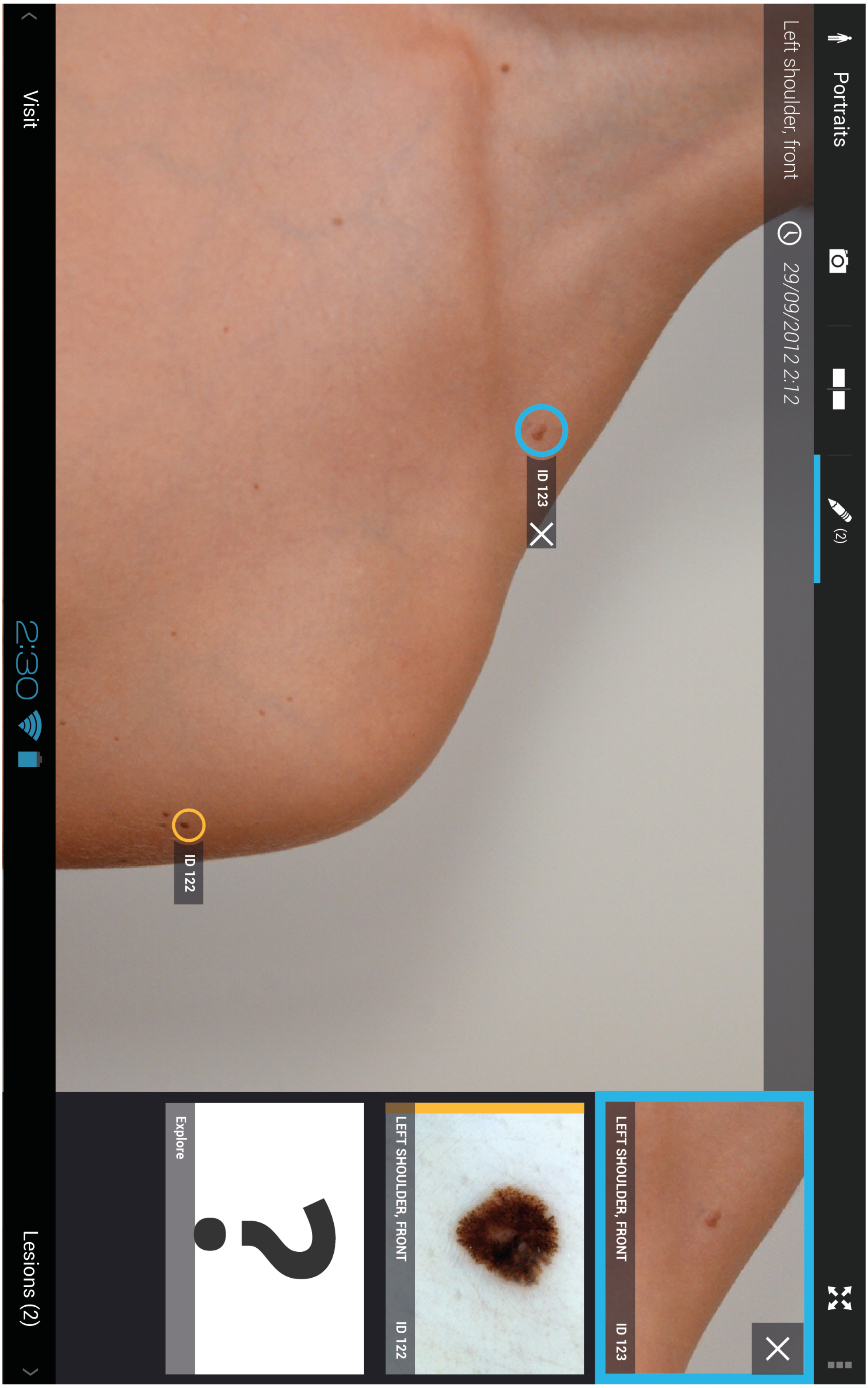

Figure 5.11: Mockup of the view group Portraits, displaying the main Mark view.

part and a timestamp (figure 5.11). Lesions can be marked via simple tapping on the photograph. Marked lesions are inserted in a dedicated portion of the screen at the right side of the portrait, at the upmost position in the gallery. As a new naevus is marked, it is automatically segmented and given an unique identification number; a detail of the lesion in the context of the portrait is extracted and used as a placeholder image in the gallery, and will be later on reused to locate the lesion; the spot that corresponds to the lesion on the full boody image is circled and labeled with the lesion identifier; the counter for lesions within the portrait in both the stepping and the view buttons is updated. After lesions are diagnosed and dermatoscopic photographs are taken, the mark circle acquires the colour code for the diagnosis, and the image in the gallery is updated. Selected elements are surrounded in the portrait by an additional, slightly larger cyan circle, and present an affordance for unmarking. The marked lesion gallery is automatically populated with lesions from previous visits. The gallery also presents, as a bottom item, a placeholder to initiate dermatoscopic exploration of the area without previous marking. However, in this mode it will not be possible to take the dermatoscopic photograph: the user will be required to mark the lesion first, and enter the Dermatoscopic camera view a second time. As per convention within the interface, lesion thumbnails can be directly interacted with to enter the relative Dermatoscopic detail, together with the next button and circular navigations, which will prompt to the currently selected lesion (figure 5.12).

The action bar offers a single button, that can be used to view the portrait in full screen mode. All interface elements but the image and the description overlay will be hidden, with the sole exception of the full screen button that is needed to return in normal operative mode. Marking is possible in full screen mode, but the gallery will only be updated once the user returns from full screen. This view control is useful for dermatologists in order to replicate the impression they are used to with the patient's skin, enhancing it with the ability of pinching to zoom and marking lesions with a single tap, without requiring excessive attention to the interaction accuracy.

Portraits - comparison

In comparison view, the current portrait photograph is compared one-on-one with previous versions (figure 5.13). The selector for said versions is coherently on the left of the screen, comprised of labels that represent the distance in time from the current day of the available shots. The two photographs are awarded the totality of the remaining screen space. Both photographs persist the identification pattern through the top overlay strip with position and timestamp. However, as portraits from previous

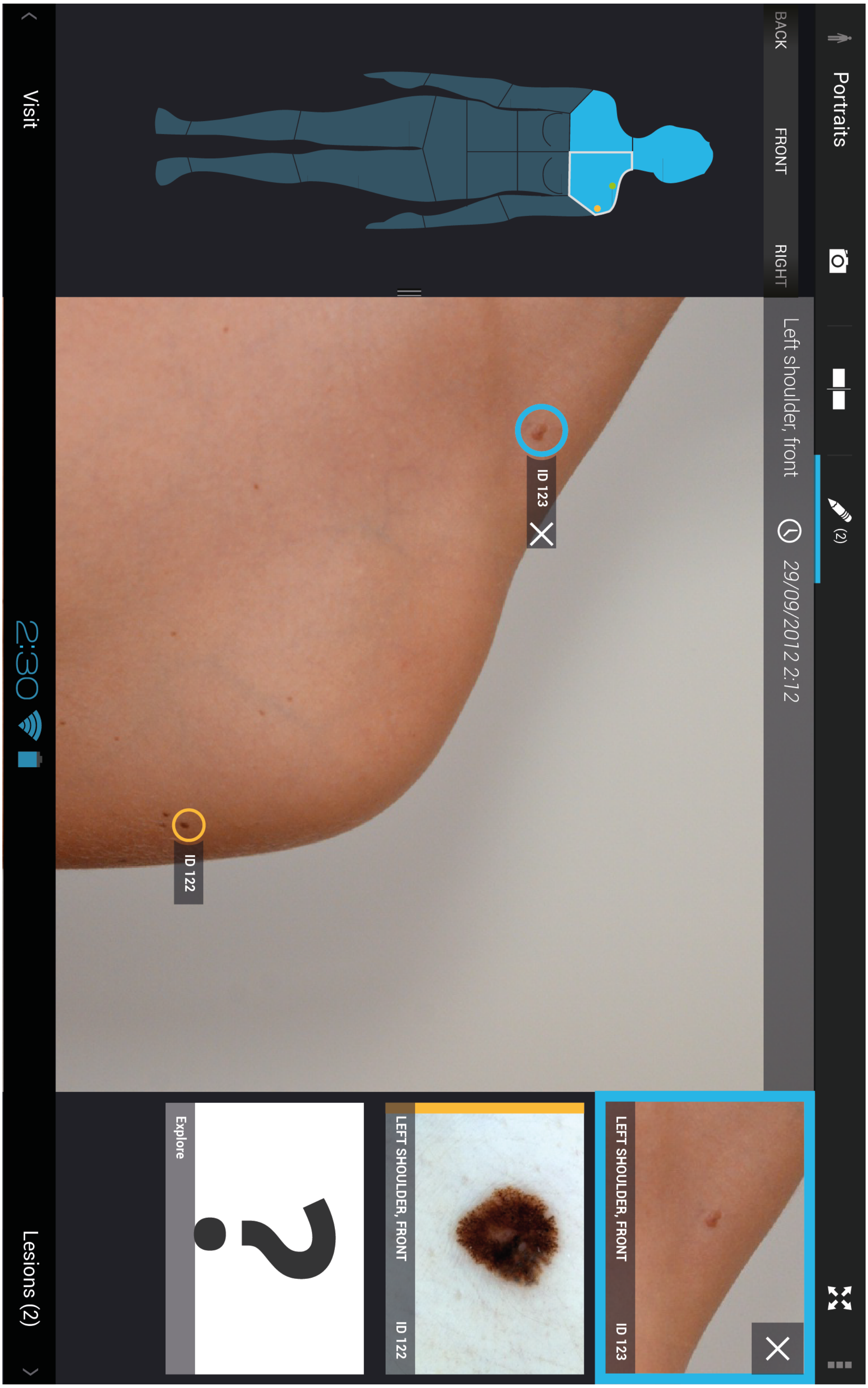

Figure 5.12: Mockup of the view group Portraits, displaying the Mark view, with the navigator panel open.

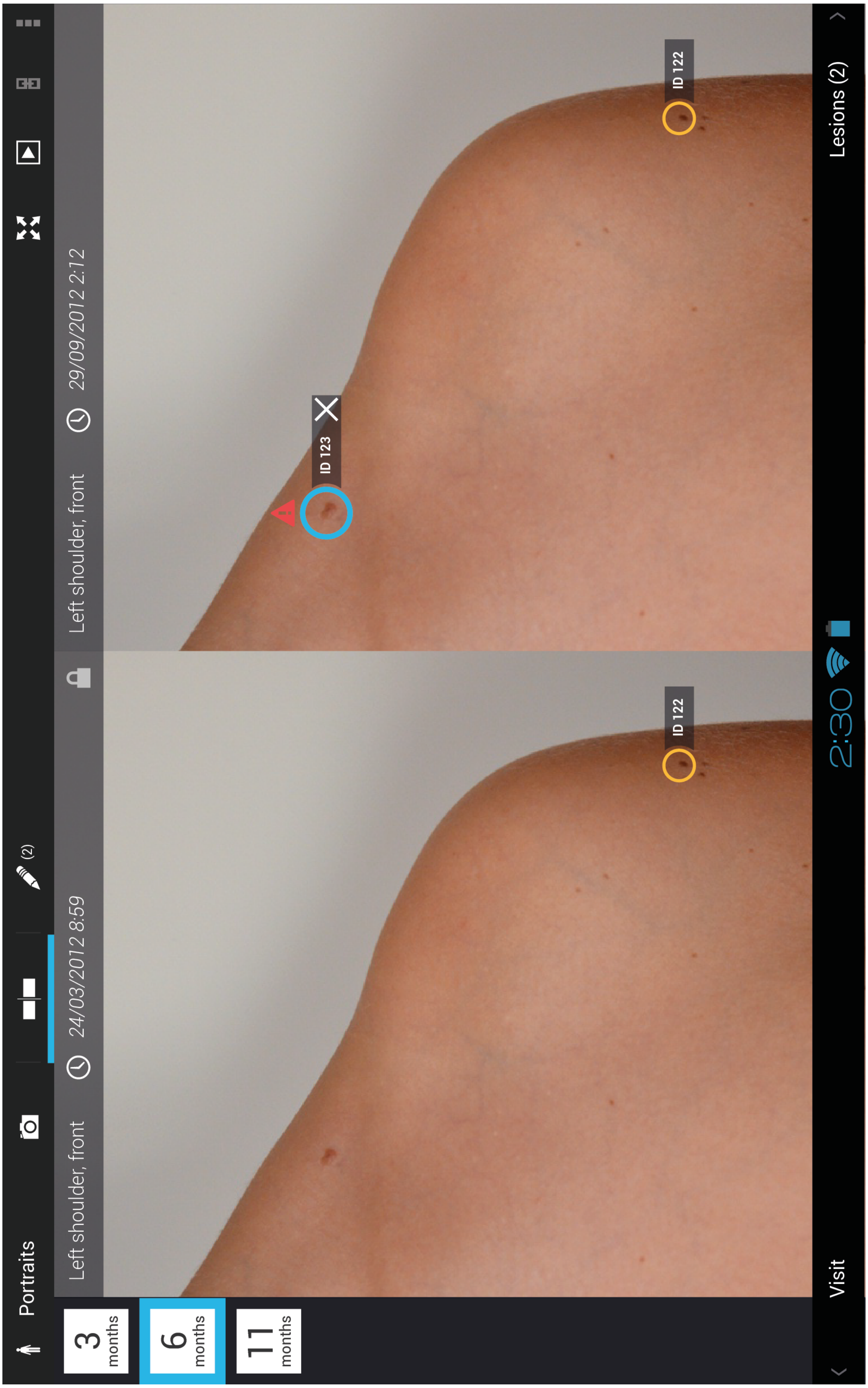

Figure 5.13: Mockup of the view group Portraits, displaying the Comparison view.

visits cannot be modified, the older photographs presents a lock icon in order to notify that it can not be edited. If the application finds new lesions that were not present in the preceding photographs, they are automatically marked in the new portrait, and are highlighted with a warning sign.

The action bar, together with the full-screen button, presents as well a slideshow button, that enters full-screen mode but displaying only one photograph at a time instead that side-by-side; image change in slideshow mode is performed consistently via circular navigation. Slideshow view is in example useful for letting dermatologists compare a previous version of the portrait with the actual skin of the patient. The last button in the bar toggles scroll lock for both the photographs - that is, when disabled, moving or zooming one of the photographs will not affect the other, and vice versa.

Portrait - camera

The camera view permits to update the photograph for the portrait for the current visit (figure 5.14). The great part of the screen, as with the mark view, is dedicated to the image - or the live camera input. In order to ease comparison, reproduction of the same pose in the new versions of the portrait is important. For this reason, the outline of the baseline version is displayed in overlay with the camera input as a guide, and is coloured in such a way that it indicates when the tolerance between the poses is acceptable. The panel on the right comprehends the description and timestamp for the current photograph on the higher side, the highlighted portrait area in the silhouette for immediate location on the lower side, and camera controls in the middle. Along the border of the circle that delineates the control area are the delete, undo and redo buttons. The center of the control, brightly coloured to underline its relevance for the task, is a button that is multifunctional yet coherent in operation. When entering the camera, the latest version available of the image is presented; pressing the plus icon of the button, the live input from the camera is displayed, and the icon itself changes to that of a camera diaphragm, in order to symbolize the ability to take the photograph. Once the photograph is taken, the live input is substituted with the newly taken photograph, and the icon changes to that used for update operations, implying the possibility to retake the photograph.

Lesions

The structure for the Lesion view group is almost symmetrical to that of Portraits. The only permitted step operation is that of going back, as Lesions represent the last

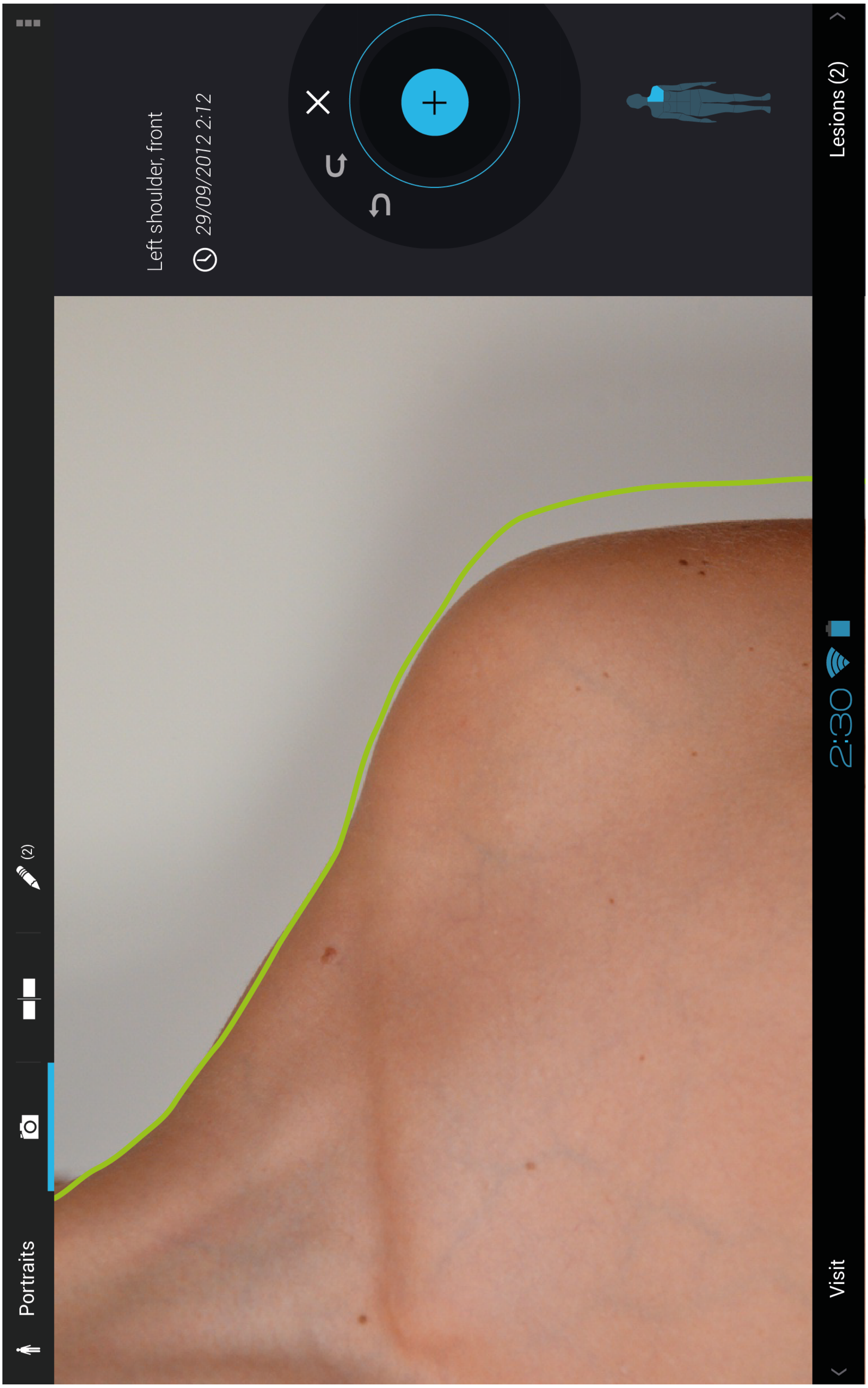

Figure 5.14: Mockup of the view group Portraits, displaying the Camera view.

level of hierarchy of screen groups; the back button is associated to either Portraits of Visit, depending on where from the user navigated into the Lesions. The subviews that comprise the group are the camera, comparison, and characterization, as well as a navigator. Likely to how it is represented and accessed in Portraits, the scrollable columns of the Visit lesion overview are replicated into a tabbed pane structure. The tabs, however, are organized differently from those in the overview, as their function as navigation elements would be limited. The tab categories that are adopted instead are divided into two static ones, that is all the lesions ordered by severity of diagnosis and the lesions from the previous visit, and two that dynamically adapt to the selected naevus, that is the lesions from the same portrait, and different historical versions of the same lesion. Thumbnails are identified in the most significant way for the context using the same overlay, and triaged with colour codes whenever appropriate, as in the lesion overview.

Lesions - characterization

All considerations made previously for the Portraits mark screen apply for this view. However, some relevant differences can be recorder regarding the panel on the right of the image (figure 5.15). In this area are presented the tools for rapid characterization of the lesion. Diagnosis input is eased by a smart medical vocabulary that is continuously filtered as the user inserts letters. Prescription can be chosen with one tap as one of three radio buttons corresponding to excision, follow up or healthy naevus. Further specification for the prescription can be specified via an editable spinner whose content adapts to the choice made with the radio buttons. Moreover the photograph can be characterized using widely popular rules such as that of ABCDE with direct toggles - the characterization method can be changed at runtime via the update button on the section divider, and the preference can be persisted in the global settings. In addition to that, the user can add custom annotations that will be parsed in background for significant tags, in order to permit faster research.

Lesions - comparison

The Lesions comparison view maintains all the criteria of the Portraits comparison view(figures 5.16 and 5.17). The principal difference is that on the bottom of the compared images are present the silhouette and the detail of the full body photograph that are needed to immediately and accurately locate the naevus. The space taken from said localization elements not only is essential to the dermatologists, but also would otherwise be wasted, as dermatoscopic lenses impose a circular vignetting to the

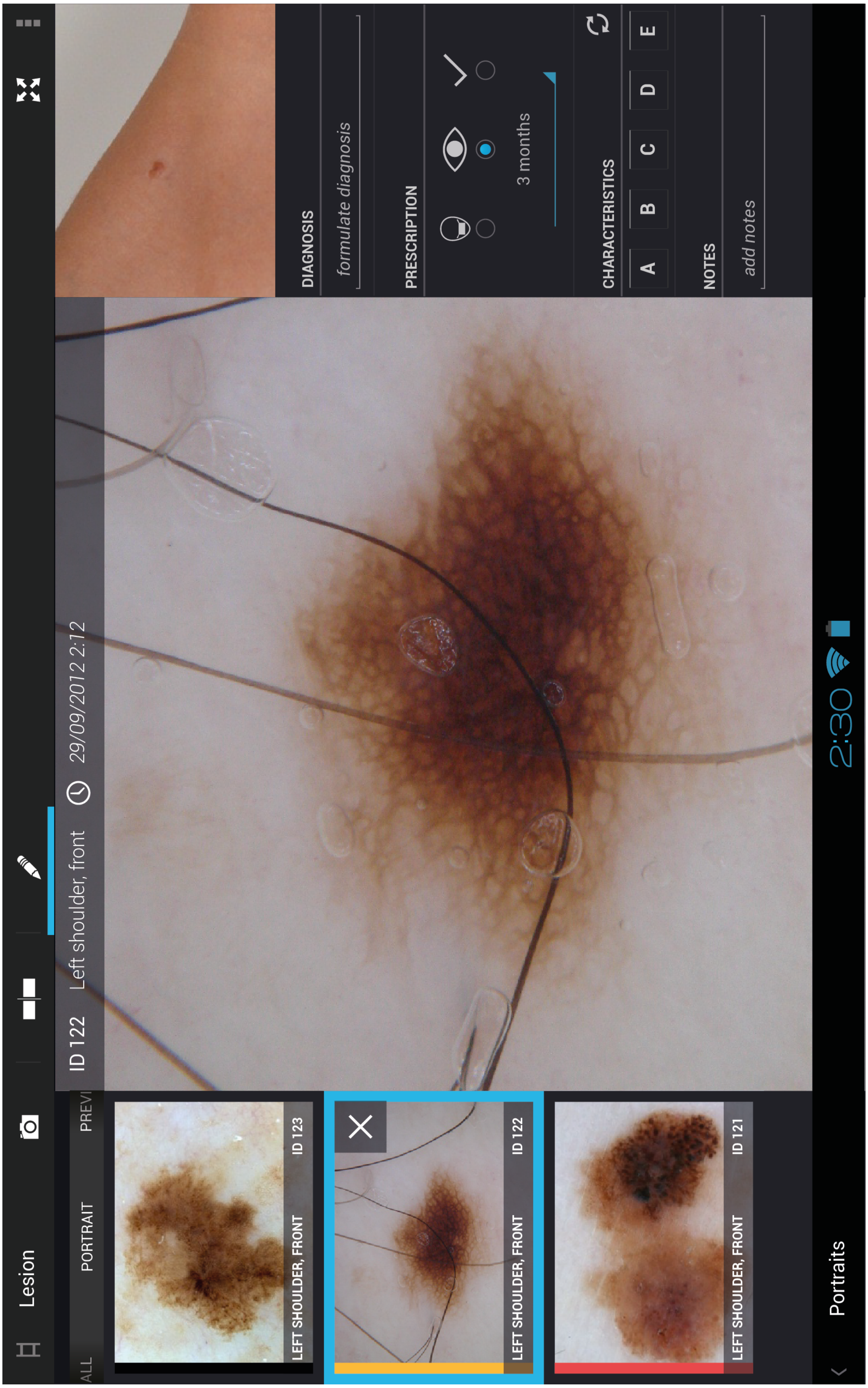

Figure 5.15: Mockup of the view group Lesions, displaying the characterization view

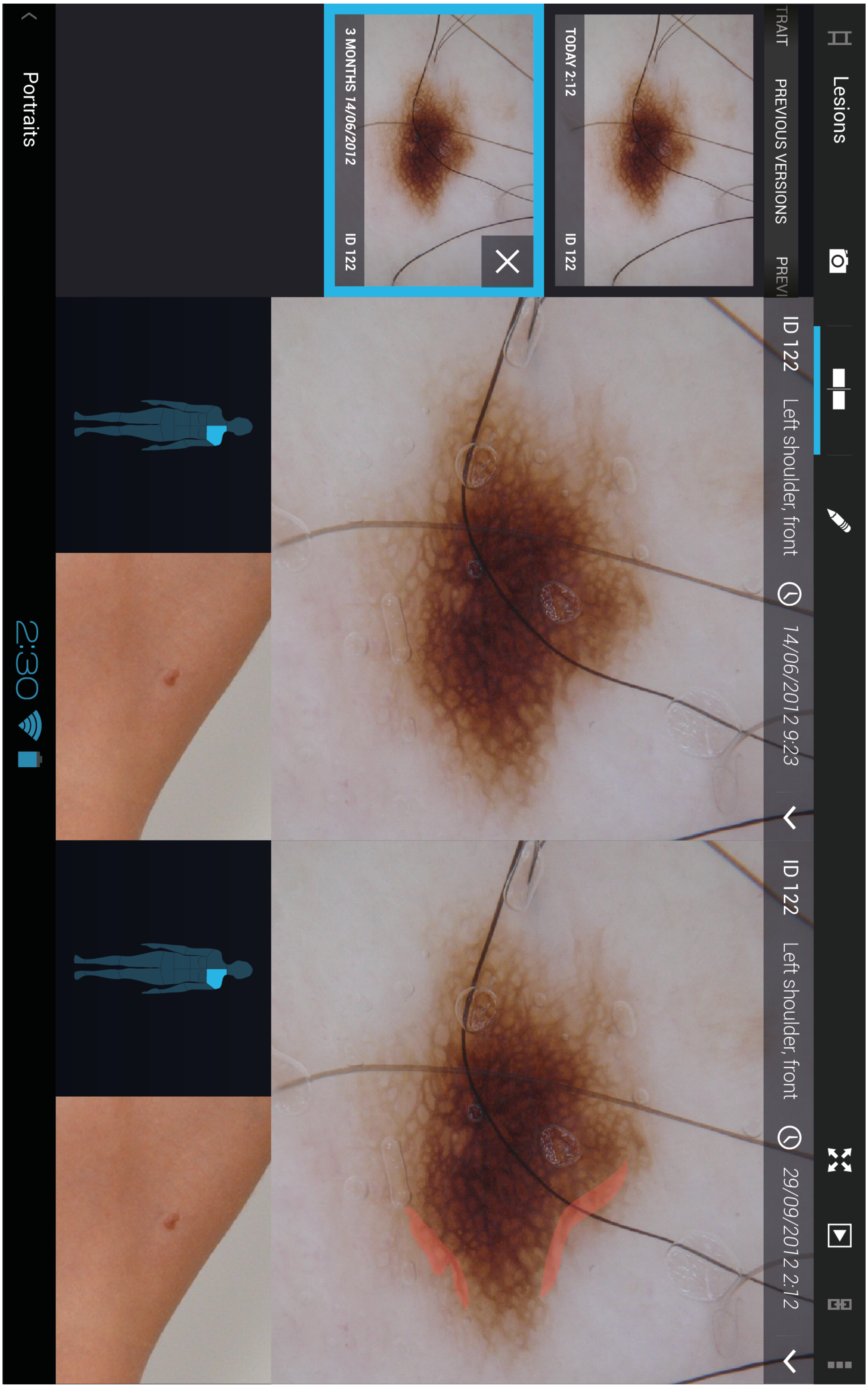

Figure 5.16: Mockup of the view group Lesions, displaying the comparison view

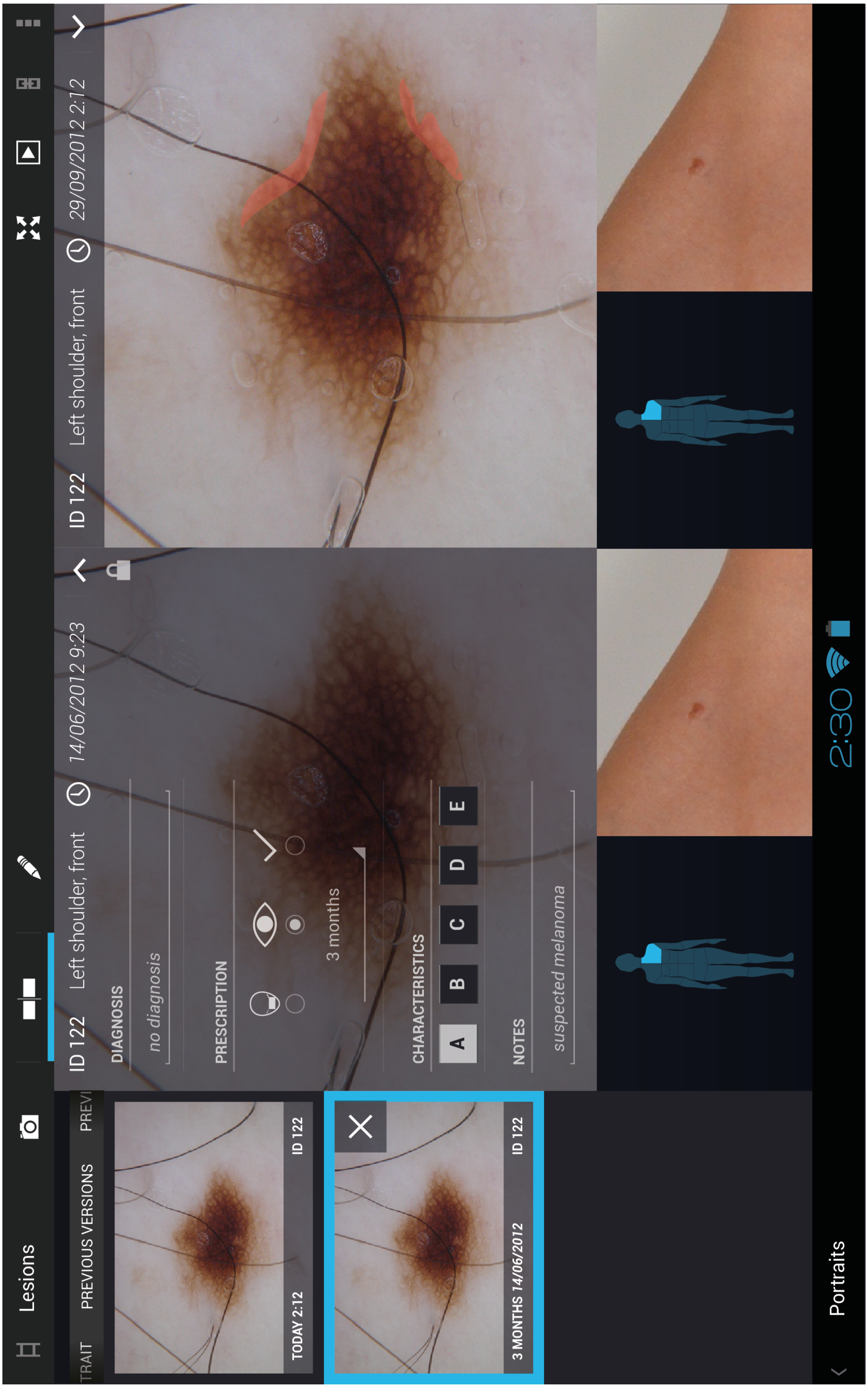

Figure 5.17: Mockup of the view group Lesions, displaying the comparison view. It shows how the overlay on the picture is used to report lesion characteristics.

images that therefore are limited to a square aspect ratio. Another significant difference is that, as suggested by the affordance on the right edge of the description overlay, and as coherent with the patterns used in the other views, the overlay can be expanded into a drop down drawer to access diagnosis, prescription and characterization information for the lesion. Likely to Portraits, lesions from previous visits cannot be modified - they can, however, be erased.

Lesion - camera

The camera view for lesions is designed under the same umbrella of principles and elements as that for portraits (figure 5.18).

5.3 Orientation management

While the application finds its natural setting when the device is in landscape mode, some users might prefer to operate some views with the device oriented vertically. Landscape is in some cases a better handling choice, in example when the user wants to use the device one handed, as the barycenter of the device is more easily reached with the tips of the fingers. Even considering that most photographs will mainly fit in landscape proportions, as the patient is most of the time laying on the doctor's couch in front of him, sometimes the position of particular lesions might be better reachable with the tablet in portrait mode. For these reasons, it has been preferred not to lock the application orientation, and let the user operate the device the way he finds more natural, according to the circumstances.

In order to maintain functional parity in both landscape and portrait modes, and coherent behaviour between functional groups of elements, several alternative solutions might be considered. There are four main approaches to deal with the change in width-height ratio, each with its own merit. The applicability of the methods is principally influenced by the inherent form of content, and the displacement of functional groups. While the main layout often needs to be adapted in order to accommodate the different visual flow, it needs not to be altered in a way that disrupts key paths and inhibits reachability of user goals. In order to conserve consistency, the following patterns are typically used:

- Shrink: in an overview-detail screen, the proportion of the two panes remains constant, while content adapts to the diminished area. This approach is the easier

Figure 5.18: Mockup of the view group Lesion, displaying the camera view

to implement, but often the less visually appealing in text-based screens, as it often leads to awkward spacing, line breaks and overfilling of elements.

- Collapse: again in an overview-detail scenario, the left panel is partially compressed to leave space to detail, which is often the main focus of action.

- Hide: when it is not possible to compress further the overview panel, it can be hidden from sight, letting user to summon it back via an on screen affordance. A generalized version of this pattern is used with circular navigation, where the views of the different view groups are continuously linked, and in the internal screens the previous levels are preceded by a summarized navigator, which can be recalled via the position element. This is coherent with the Android guidelines, considering that the system's hierarchical navigation can be seen as an edge case of circular navigation.

- Stack: in the case of multiple functional blocks arranged in separate panels, they can maintain their position, thus resulting stacked vertically instead of horizontally, eventually changing the orientation of content and controls.

The policy applied to each view is different and depends, as discussed, on the particular need of space of the displayed data, and the positioning of main functional clusters. However, corresponding screens in different view groups are treated the same way, to maintain a common interaction framework. For Login and Home view groups the most effective solution is shrinking: the displayed data is minimal, and modifying the relative position of elements could badly affect the propension of the user to identify in these introductory steps. In the Settings view the best option is that of collapsing the overview panel, as it only displays the names of the configuration section and groups, while the readability of the single configuration items must not be compromised. The Patients and Agenda view group must be split into different screens in order to diminish the cognitive efforts the user must make to absorb the rich presented data. As the groups are organised horizontally from the most general to the most particularized view, the extended hide pattern can be applied consistently carrying on the circular navigation principles. The Patients screen should be split in a first screen containing the patient list and the identification and update panel, and a second screen with the details of the patient's electronic health report, so to maximize the area dedicated to the content. However, even if circular navigation is applied straightforwardly, an on screen affordance should be placed on the first screen in the identification panel in order to underline the presence of the second screen. The Agenda view group is best split into three screens, one for each view. In order to maintain the ability to summarize at a glimpse the advancement of the visit, and give a comprehensive outlook on its outcome, the Visit views should be rotated adapting the content to portrait mode. While the padding around components would significantly diminish, it is essential not to lose the overview capabilities that are the underlying goal behind the view group. The approach used in the internal views, that is, the Portraits and the Lesions, is that of stacking. This is due to the fact that the layout is constrained in its position by the centrality of the displayed content, which must remain the focus of the interaction. As discussed in the requirement analysis section, the primary task of dermatologists is observing - making content move or shrink would be more disruptive to the experience that introducing functional disparities. While functionality is always maintained, two main differences from the landscape operation have to be introduced in order to respect the natural interpretation of the modified layout. In Portraits, the navigator drawer slides in from the left side of the screen even in vertical orientation. In Lesions, however, the navigator galleries are displayed at the top of the screen. This is caused by the fact that stacked panels are needed to render non ambiguously the relationship between the navigation and the content change in the left-hand- side of the comparison. As the tablet can be rotated in both ways, it is important to maintain an univoque sense while stacking panels, in order to reinforce the predictability of the result: left to right maps into top to bottom, in accordance with cognitive theories on view and reading flow in Western populations. This expedient is not needed in Portraits, as the navigator for comparisons is separated from the navigator common to the other views in the group. While this approach breaks on a lesser extent the circular navigation pattern, it is needed to maintain coherence and not to obtrude action flow in this secondary mode. The principal posture for the application, intended for landscape mode, should not be corrupted for what is considered a collateral, subordinate deviation.

Chapter 6

Validation

The visuals and behaviours that have been investigated via qualitative research, modeled using goal-directed design techniques, and embodied in a visual framework, are not guaranteed to be effective in interacting with the user, regardless of the effort spent on the design. The human factors in interpretation are unpredictable, and even the slightest detail could spoil a finely crafted experience. This is perhaps one of the reasons why the "less is more" design principle often results in successful products. However, highly-efficient interfaces can follow the minimality route only to an extent: complex functionalities and advanced controls must be visually differentiated, operation flow dominates over data, exceptions to the average usage patterns are frequent and cannot be avoided. While uncertainty makes usability design an interesting challenge, the efficacy of an interface must be assessed in order to bring the development to its final form. The scientific communities involved in human-computer interaction are active in exploring metrics for interface usability [46, 49]. However, the rapid change in software and hardware platforms, and the novel use of technology in everyday life, make applicability of even fairly recent methods controversial: the goals of users and what they expect of technology are changing at an unprecedented rate, and so is the perception of the vague notion of "performance". The definitive metric for interface evaluation remains user testing.

Before discussing how the visual framework should affect the user experience, key path scenarios were briefly discussed. Key path scenarios are a preliminary sanity check for how smoothly main tasks can be executed. Designers use them to iteratively refine the efficacy of the interaction model. Once the critical and most frequent tasks are covered, and a reasonably detailed interface comes to a stable form, more sophisticate scenarios can test design robustness. Validation scenarios take the role of the devil's advocate in testing lateral interaction paths to expose the weak points of the interface. Validation scenarios, as defined in Cooper's "About Face", can be divided into three categories:

- *Key path variant scenarios*, that represent alternative decisions at some point in the user's main interaction paths.
- *Necessary use scenarios*, that question operations that are expected and must be performed, but are not in the key path because they are uncommon.
- *Edge case use scenarios*, that represent atypical situations, such as those that arise when a user performs an operation that is not desired or intended per se.

Validation scenarios share the beneficial properties of economicity and immediateness of administration in combination with great explorative power. However, albeit useful, these tools cannot substitute user feedback. The designer or the developer that know the internal mechanisms of the interface, even feigning short-term amnesia, cannot avoid being biased in their interaction, as patterns are already interiorized and automated. Moreover, the goals of users are defined by their life experience, and thus cannot be simulated beyond a reasonable approximation.

Usability testing is a collection of procedures that aim at giving an evaluation, as objective as possible, of the characteristics of the interaction between the user and the design. By its nature, testing is best performed in a phase of development that precedes definitive coding, but is at least concomitant with the refinement phase. In the later phases of the design lifecycle, in fact, a coherent concept is formulated and sufficient detail can be employed to concretize an experience that can be related to that of the final product in terms of completeness. By the same token, testing while farther into final code development would require too much effort if radical adjustments were to be made, and would tend to delay indefinitely the expected release date.

User testing can be performed using several techniques, that might differ in scope and methodology, but that all share the following basic structure:

1. recruit representative users;
2. ask users to perform realistic tasks;
3. ask users to verbalize their thoughts in a stream-of-consciousness manner as they interact with the design.

It is often difficult and expensive to conduct the tests in a location representative of that where the device will be used. A facilitator is therefore needed to mediate the session, in order to allow suspension of disbelief - i.e. the phenomenon according to which a user is able to immerse himself in the test even if conscious of the fictitious environment. The test session can be recorded with several instruments, from screen grabbers to webcams and eye trackers, for later evaluation. The reaction of the user, the impression he gets from the interface, his ability to recognize the elements without guidance are all data subject to be assessed, and are usually quantified in terms of time employed for a task, or number of times particular aspects of the interaction take place.

The measurements that are the outcome of user testing are useful to evaluate naming and labeling, broad organization of the information, and discoverability of elements of the interface. While these aspects are fundamental in determining the immediateness of a design, they can only assess first-use cases for novices.

Testing how expert users would interact with a high-efficiency interface at their fiftieth use is complicated by several factors; with the mole mapper being a particularly difficult case. The most immediate impediment is that users should be monitored for a prolonged period in time. Another rather obvious difficulty is that the tasks performed by expert users are often complex and interrelated, and measurements on a single task may not be significant when paced in a broader context. Another issue is that mole mapper is used in a specialised environment for tasks where the patient's life is at risk: suspension of disbelief, whatever the ability of the moderator, would be difficult to obtain. Furthermore, high-efficiency interfaces induce in skilled users automated behaviours, which are often omitted when verbalizing conscious reasoning. In addition, quantitative metrics on convoluted and interdependent tasks are difficult to interpret. They simply expose a particular flaw on one point of the interaction without providing an explanation that can lead back to the general framework. Fixing the particular fault might open a consistency breach in an apparently unrelated part of the interface, thus worsening the overall structure. [5, 15]

For the reasons above, traditional use-case testing in isolation appears inappropriate for mole mapper. Instead, different methods should be applied, in order to evaluate the performance of the interface during a longer time frame, and in situations where the user of the device can operate with full autonomy. One of these techniques is diary study. [22]

[45] suggests, as a preliminary step, use of low fidelity prototypes. However, to better engage in dialogue about the design without the interference of a detailed visual framework, in the case of mole mapper a higher level of realism should be employed to expose nuanced interaction. Considering that in devices meant for high efficiency the user experience must be fine tuned, a functionally semi-finite and visually complete prototype is therefore needed. [3]

Thus, the proposed user testing method, is that of letting a small group of users keep rough prototypes, to perform or simulate tasks of their routine in the real application environment, and to record their experience over two weeks. An introductory traditional user testing session should be performed beforehand, in order to evaluate the time needed to become familiar with the interface idioms and the possible usefulness of supervised training, as well as to record a preliminary evaluation. At the end of the testing period peer interviews should be used to clarify user behaviours and impressions.

Instead of extracting quantitative measures for evaluating the design, once a working prototype is complete, developers themselves can conduct in parallel other types of objective testing. For example complexity analysis [46] can be iteratively employed to find and quantify impediments in interface usage. Quantitative metrics are found to be more significant and to provide a more objective interpretation, while the methodology itself is time-effective and requires minimal effort.

Chapter 7

Implementation

The implementation of mole mapper requires precise planning and preparation. It is a complex software that supports a vast range of tasks. The advanced functionalities offereb by the application combine aspects of image processing with sophisticated data management and and rich user interface. On top of this fact, mole mapper's goal of high efficiency requires particular attention to performance and responsiveness. This is even more challenging because we aim for a mobile, portable device with limited computational resources.

Another issue is that mole mapper is the core component of the CiS platform. It cannot be optimized in isolation as it will serve as a hub for the other devices that will complement its functionalities. For this reason mole mapper's architecture must be planned taking into detailed acount from the very beginning the requirements of, and the interactions with, the remaining components of the system.

Mole mapper is currently still in the early stages of software development. As mentioned above, stability and forward compatibility with the rest of the CiS platform are among the priorities of mole mapper; this has lengthened the planning phase appreciably. In addition, we are still evaluating the actual feasibility of some desiderata for the backend; this, too, has contributed to our choice to delay the development phase.

While we could not implement a prototype, this section discusses the chosen implementation approaches, and defines the architecture of the interface within the framework of the whole system.

7.1 Design pattern

Mole mapper will be the central unit in the CiS platform. It will expose storage and processing functionalities to external devices, effectively turning them into ”thin clients”. For example, body scanner and stand-alone cameras can be connected to mole mapper in this configuration. Moreover, mole mapper will need to interact with multiple standalone agents, such as personal screener. Finally, the integration with third party services, such as hospitals’ pre-existing authentication facilities, will be performed with custom protocols and dedicated modules. For these reasons, the structure of mole mapper must be at the same time easily maintainable (to permit rapid adaptation and updating), consistent (to provide a stable reference for other devices in the platform), and modular (to maximize code reusability).

The need for discipline in mole mapper’s development can be mirrored in software engineering design patterns [14]. As with interface design patterns, software patterns provide general, reusable solutions to recurring problems within a given context. Patterns allow developers to rely on trusted methodologies, without the need to reinvent them.

Given the requirements for mole mapper, it is essential to separate the internals from visualization and data management. One of the most popular patterns to resolve role distinction within interface code is the Model-View-Controller (MVC) pattern. Following MVC, the application data queries must be defined in the Model component. The Controller interprets user input, obtained through the View, into internal functions, manipulating the data in the Model. The View is the user interface, strictly speaking: its content reflects the Model, and it is updated as data changes.

While MVC is a clear and well defined way to deal with the problems of mole mapper’s interface, its implementation on the Android platform would be suboptimal in terms of programming overhead. In fact, the system already presents its own peculiar way for managing interface and internal logic, which is partially different from standard MVC prescriptions.

In particular, the actual Activity class, which is to a first approximation the entry point for each screen of the application, does not extend Android’s View class, which is used for laying out interface elements. However, the Activity does manage window display and event handling on interface elements, and as such it cannot directly correspond to the scope of the Controller module of the MVC pattern. Moreover, as Views in Android are typically instantiations of layouts defined via an xml file at compile time, it is common practice to create and manage additional interface elements at runtime from inside the Activity. As such, the Activity can be thought of as a hybrid of View-Controller. Separating View functionalities from Activities would be extremely inefficient for both the developer and the hardware, and would negate developers several powerful features of the system.

Nevertheless, a pattern that derives from MVC can be successfully employed, obtaining improved integration with the platform: the Model-View-Presenter (MVP) pattern [38]. In MVP the role of the Controller and part of the View's logic are taken by the Presenter, while the functional interconnection is slightly modified. The definition of the modules in MVP is the following:

- The Model defines the data to be displayed or otherwise acted upon in the user interface.
- The View is responsible for the graphical rendering of data, to route to the presenter those events related to the graphical manipulation of data.
- The Presenter retrieves data from repositories, processes it and formats it to be displayed in the View.

The original formulation of MVP intended to make the View completely unaware of the model and removed from all logical decisions. However, subsequent implementations, in particular Web applications, restored a limited inclusion of control logic in the View, to enhance client operation and responsiveness.

In the latter formulation, it is possible to apply MVP in Android almost effortlessly. The View role in the pattern is taken naturally by Android's Activity, which serves as an entry point, event router and window manager. The Model is stored into appropriate DBMS or data warehouses. The Presenter corresponds to the classes implementing the internal logic and managing the database.

7.2 Services and Fragments

Before presenting the structure for mole mapper, a short premise must be made on some peculiarities in Android application fundamentals. While it is not my intention to give an overview of the system and of programming common practices, these considerations are needed to understand the motivation behind the specific subdivision.

In particular, one should note that Activities, which correspond to the typical entry points of the application, are strongly tied to a single screen, to enforce focus on a single task. Applications are therefore comprised of several Activities, which can share data and status when taking over from each other. In order to maintain a running element which is not bound to what is displayed on screen, a fourth application component type, the Service, must be used. A Service is a component that runs in the background, similar to an operating system daemon, to perform long-running operations or to perform work for remote processes. Services can be started by other components, such as an activity, which can optionally bind to the Service in order to interact with it. Mole mapper will make use of Services to maintain data cached and always available, as well as to perform image processing operations in background, and controlling connection and synchronization with the rest of the CiS platform.

Another important issue is the introduction, since Android 3.0 (API level 11), of the Fragment as a substructure of the Activity. Fragments were intended to support more dynamic and flexible UI designs on large screens, such as those of tablets, where the extended area could present more than one typical Activity at a time. In fact Fragments can be considered the representation of the behaviour of a portion of the interface, with its own lifecycle and user input management, within the context of an Activity. The main advantage in using Fragments to build multi-pane views is that they allow one to maximize modularization and reusability of code. As an example, an overview-detail screen built using two Fragments for a tablet could be ported with minimal adaptation - if any adaptation is needed at all - as a smartphone interface where the two panels are accessed exclusively in succession. The approach that will be used in implementing mole mapper compound view groups will be that of embedding multiple Fragments within a single Activity, in order to be able to dynamically swap in and out the single views with ease.

7.3 Structure

After introducing the design pattern and the building blocks, it is now possible to discuss the structure for the interface, in the context of the application.

Mole mapper has to comply with the specification of the standard Android components. As discussed, Android applications do not present an architectural backbone, favouring instead a succession of linked Activities. The logical division into views, and their clustering into functionally-related groups, proved to be robust enough to be employed to this end without modification. The view groups map directly into Activities, while the single views are translated into Fragments (figure 7.1). This way Activities centralize and deduplicate the data to be displayed, while Fragments allow one to deal with contextual Actions coherently. Activities arbitrate communication in between Fragments from their structurally higher position in the application hierarchy. Navigation is, strictly speaking, performed at the Activity level, managing transitions while minimizing and simplifying long-term code management.

Additional Fragments tied to separate activities are introduced to implement the occasional full screen and slideshow modes: in these circumstances the whole screen must be replaced and displayed in isolation from the normal application environment.

Given the strong correspondance between several Fragments (e.g. the full screen, slideshow, comparison and camera Fragments), inheritance and polymorphism offered by the language will further minimize the number of lines of code to be written, and increasing project maintainability.

Dedicated services perform image processing functions both online and in background, allowing data prefetch and increasing interface responsiveness. Image processing services are launched when needed by specific Activities, and are executed periodically if unprocessed data is present.

All information used by the application is stored in a database accessed remotely. This is unavoidable given the limited processing and storage capabilities of the tablet. A remotely accessed database is also essential in preparing for future communication with the personal screener. While the DBMS will be remotely accessed, a database manager Service will run locally. This element will formulate optimized queries to the actual database, while serving as a cache for data already retrieved, or data most likely accessed in the near future. The manager will also take responsibility for translating database records into data model object instances, and vice versa. The application will exchange data with the manager under a general interface, and object type will be qualified immediately before being handed to the individual views, in order to expose a minimum set of methods in the manager. Again, this will improve maintainability, stability of the structure and compatibility with external devices.

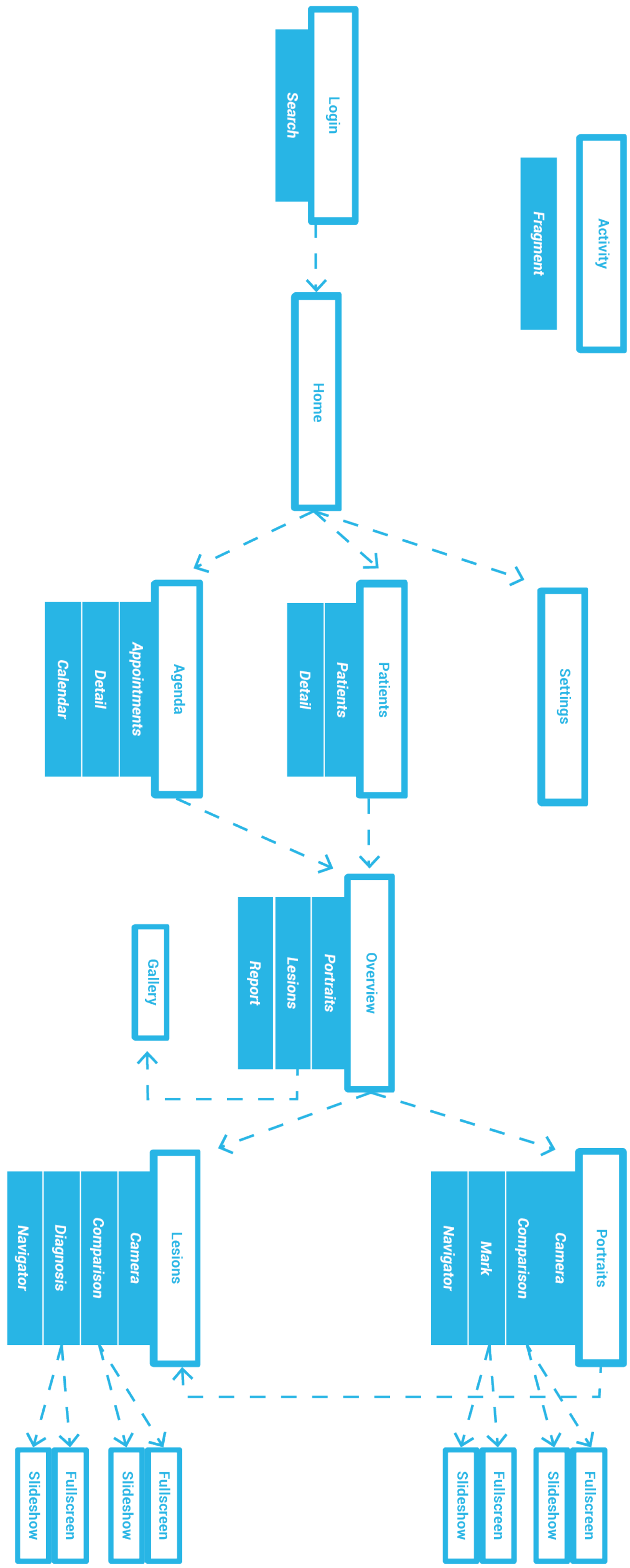

Figure 7.1: Mapping of the interface into Activities and Fragments

The database manager will be developed as a central module for communication with the application, but the backend will present a plugin-like structure to provide adapters for third party information systems such as Galileo. This method makes the application oblivious of the underlying source, and allows abstract and uniform data access. Protocols for specific needs can then be further developed at a later time without the need to refactor the internal behaviour.

The structure described above reflects the interface structure in a natural way, while allowing seamless integration of mole mapper with the other components. The requirements of code readability, deduplication, maintainability, as well as reusability are fulfilled, and the functional composition of Activities promises to be sufficiently robust to allow consistent interconnection with expansion devices.

7.4 Implementation issues

Some of the image processing primitives that had to be given for granted during the design of the interface are in fact still open challenges. Segmenting naevi from whole body images, for example, is a task that suffers from the distortion introduced by the three-dimensional curvature of the body surface. The typical illumination of daily medical practice, which is less than ideal for image processing tasks, creates shadows that can be mistaken for naevi, or it can hide naevi completely even to the eye of a human operator. Another example is that of dermatoscopic image comparison: to highlight differences between two images, those images must be *registered* - i.e., roughly speaking, rotated, translated, and rescaled to a common frame of reference. This is relatively easy if the two lesions are identical. However, when lesions evolve, evaluating when one has reached the “correct” alignment is not easy (in fact, even a formal definition of “correct” is by no means obvious). Further noise can be introduced by body hair – although our research group has developed effective techniques for hair detection and digital removal through impainting [13]. Finally,lenses can introduce complex non-linear deformations of the skin when in contact with it.

The development team is currently implementing a semi-functional prototype, which will serve as a starting point for future developments and as a tool to administer user tests.

Conclusions

State-of-the-art technology for digital dermatoscopy fails in supporting dermatologists in daily practice. Our user studies show that the main problem lies in lack of usability of the technological solutions on the market. In particular, the visit workflow is interrupted by both the unwieldy form factors of the devices, and the rigid interaction framework of the interfaces.

We addressed the demand for higher productivity through a design synthesized on persona and scenario models. This development methodology allowed us to maintain consistency with the user mental model, thus resulting in more intuitive interaction. One of the main accomplishments of the design process was the introduction of a novel navigation pattern, which rendered interaction predictable and efficient. In addition, a semantic analysis of the information and functional models allowed us to optimize screen hierarchy and user cognitive efforts, by modularizing interaction into views, rather than screens. The fluid placement of views onto the user screen provides, as an added benefit, easy adaptation to different screen factors.

The software architecture for the interface, and its interconnection with the rest of the CiS platform have been finalized. However, delays in software development of the rest of the CiS project made it impossible for us to test a "working product". In particular, we could not obtain rigourous quantitative data on the speed-up provided by our solution compared to the state-of-the-art. We did, however, define how this testing should be conducted once the rest of the CiS project is up-to-pace; and from preliminary, qualititative observations we fully expect a considerable speed-up.

In general, speed is only one of the many facets of productivity and user satisfaction. We analyzed several other evaluation approaches in the literature. Ultimately, none appear entirely satisfying. Roughly speaking, current interviewing practices are biased towards first-use usability assessment rather than expert user performance , and they all fail specifically address expert user performance under realistic working conditions. Diary studies are more accurate, but are extremely time demanding, thus being more suited to ex-post evaluation rather than to provide feedback for rapid refactoring iterations. Defining practical, comprehensive metrics for the general “quality” of the user interface will likely require considerably more effort; but they are a prerequisite for effective field tests and comparative audits.

In this regard, it is crucial to observe that our interface implementation will likely require require several iterations of adaptation to system behaviour and components. An effort should be made to let the modification process maintain functional coherence with the user and task model. While the development process is yet incomplete, we hope that the daily routine of dermatology clinics will rapidly adopt CiS. Our preliminary studies on the interaction framework and interface usability suggest that dermatologists are fully aware of the sizable improvements to their productivity promised by CiS.

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