A Mobile approach for Farmer-Computer Interaction

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Abstract

Agriculture has been responsible of sustaining and enhancing human life starting at least 105,000 years ago. Nowadays, traditional approaches to farming can be enhanced with technology, helping farmers make more informed decisions when it comes to their farming activities. Information and communication technologies, specifically, mobile phones, are now enabling farmers to improve efficiency and optimize production, while preserving resources.

However, due to limited technological proficiency, a problem emerges. The adoption and acceptance of these solutions are dependent on the skill for handling and understanding digital media and this can be a challenge in specific demographics, where age can be a constraint and access to technology, in rural areas, be scarce.

The aim of this study was to conduct a Human computer Interaction research centred around the potential end-users of a mobile application in the agricultural field. Therefore a User-centred Design methodology was followed, allowing to narrow the scope of the study, from Agriculture in general, to Prevention and Control of the Grapevine moth in Viticulture in the Douro Region of Portugal. In this process, explicit and implicit methods were used, such as Personas, Focus Groups, Individual Interviews, Field Observation and Usability Testing. Farmers and other stakeholders were involved in the all phases of the design process, from requirements gathering, analysis, design and evaluation of the prototypes created. The outcome of this study was to accommodate and support farmers' needs and expectations while also studying how these users interact with technology.

Acknowledgements

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Maria Marques

"Whatever you think your life is going to be like, just know, it's not gonna be anything like that."

Mike Mills

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Abbreviations

DDR   Demarcated Douro Region
GIS   Geographic Information System
GPS   Global Positioning System
GSMA   Groupe Speciale Mobile Association
GUI   Graphical user interface
HCI   Human-computer interaction
HTA   Hierarchical Task Analysis
hi-fi   High Fidelity
ICT   Information and communication technology
ICT4D   Information and Communications Technologies for Development
ISCE   International Standard Classification of Education
ISO   Internation Organization for Standardization
IT   Information technology
IxD   Interaction Design
low-fi   Low Fidelity
PA   Precision Agriculture
PEU   Perceived ease of use
PU   Perceived usefulness
RDD   Região Demarcada Douro
SSM   Site-specific management
SUS   System Usability Scale
TAM   Technology Acceptance Model
UCD   User-centered design
UI   User interface
UX   User Experience
VRT   Variable Rate Technology

Chapter 1

Introduction

The application of Information and Communications Technology (ICT) in the agricultural sector opened up a whole new world of opportunity. mAgriculture and Precision Agriculture (PA) are based on using ICTs to provide information and data to assist farmers when making site-specific management (SSM) decisions.

1.1 Context

The huge technological improvements in personal electronics made it possible for farmers in rural areas to access real-time information, delivered through devices such as mobile phones and tablets. Farmers are challenged when using these devices due to limited technological proficiency and the way they interact with devices that collect large amounts of data and information will have a direct impact in their farming activities. The adoption of mobile technology in the agriculture sector is dependent of the end-users technological proficiency, so it is necessary to study the existing scenario on the general use of ICTs on the field by farmers, in order to guarantee the success of mobile agriculture applications.

1.2 Motivation

This dissertation was proposed by Fraunhofer Portugal Research Center for Assistive Information and Communication Solutions (Fraunhofer AICOS) and performed there. The project consists on designing a mobile solution adapted to farmers' needs in rural areas of Portugal.

In Portugal there's a lack of research literature regarding farmer's needs and expectations when interacting with mobile agriculture applications, thus it's relevant to conduct a research, using a user-centred design (UCD) approach within the field of human–computer interaction (HCI) aiming to develop and adapt the ICT system based on the users' needs as well as the context of use.

1.3 Goals

The ultimate goal is to better understand farmers' needs and technology acceptances through user research and analysis and it'll also be necessary to:

- Conduct thorough research on visual aspects to inform the design of graphical user interfaces (GUIs);

- Develop prototypes that will explore new and efficient methods of visualization and interaction on Android devices;

- Evaluate concrete designs with real farmers;

1.4 Report Structure

Besides the introduction, this report has four more chapters. Both chapter 2 and chapter 3 are part of the literature review. In chapter 2 it's possible to take a look into the use of ICTs in Agriculture. In chapter 3, the process of user-centred design is presented. The chapter 4 presents the followed methodology, divided into phases. In order to conduct this study, the UCD methodology will be divided in four major phases:

- **Phase One - Requirement gathering**: encompasses market analysis of existing solutions, defining the research sample, research methods used and findings.

- **Phase Two - Analysis**: entails scenarios and personas creation, specification of prototype's requirements with different levels of abstraction.

- **Phase Three - Design**: where according to the specified requirements different guidelines and design principles are taken into account in order to support design decisions in the following next phase.

- **Phase Four - Prototyping and Evaluation**: refers to the creation of low and high fidelity prototypes. In this phase usability tests are performed by real users.

Lastly, in chapter 6, the conclusions of this study are presented.

Chapter 2

Information and communications technologies in Agriculture

With the increased use of Information and Communications Technologies (ICTs) in the agriculture field various areas of opportunity arise. This chapter is composed by two main topics: mAgriculture and Precision Agriculture. Section 2.1 will address the various types of mobile solutions for agriculture, examples of those in the market, and the potential of mAgriculture. Section 2.2 will address the history of Precision Agriculture, technologies used, the benefits, concerns and drivers of adoption of this management approach.

2.1 mAgriculture

E-Agriculture is an emerging field focused on the enhancement of agricultural and rural development through the use of ICTs. The mobile phone has become one of the most used ICT devices globally and with the increase of it is penetration in developing countries' markets, as presented in Fig. 2.1, there's an opportunity to impact and empower small holder farmers in rural areas. Therefore mAgriculture or mAgri is a subset of E-Agriculture and is the research area concerned with the improvement of the economic environment through the use of mobile computing.

Since the introduction of tablets and the higher adoption of smartphones and tablets by farmers, mAgriculture has also become relevant in developed countries [WEU12]. With the use of mobile applications it is possible for small holder farmers in rural or underdeveloped areas to have access to a number of services, from simple tasks like checking the weather [Acc17, Agr16, Bar16] to more complex ones like pests and disease diagnosis [Esp16, PEA17].

It is important to understand the context in which mAgri has evolved and adapted to user's needs. Some mAgri solutions rely on Short Messaging Services (SMS) [2] or Unstructured Supplementary Service Data (USSD) protocols [air15], sending brief messages to communicate with

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[1]http://data.worldbank.org/indicator/IT.CEL.SETS.P2?end=2015&locations=XL&start=1960&view=chart

[2]https://www.mfarm.co.ke/
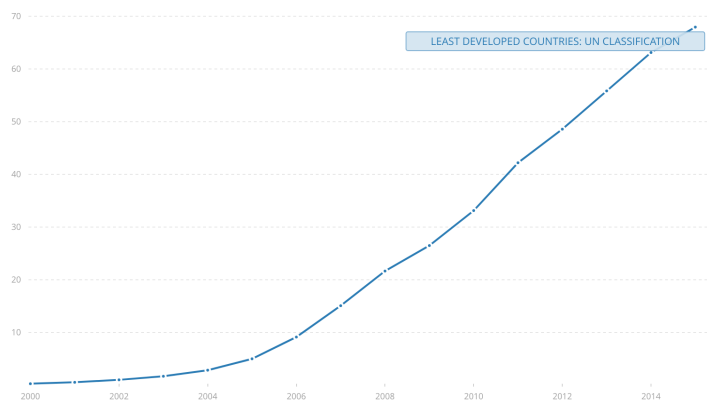
Figure 2.1: Mobile cellular subscriptions (per 100 people) in Least Developed Countries: UN Classification [1]

farmers. These require less bandwidth, making them less expensive than a phone call but are limited by other factors such as low literacy and lack of knowledge [WSC⁺16]. SMS compared to USSD can have a higher cost and be a slower service and also has a restriction on the number of characters [Ira10]. Other solutions rely on Interactive Voice Response (IVR) [3]. This can be a great way to overcome the obstacle of illiterate users. All these technologies can be combined and some proposed solutions encompass SMS, USSD and even IVR all in the same service, while other services evolve and adapt to their costumers' needs, like the Airtel Kilimo service that evolved from a SMS & IVR solution to USSD only [air15].

Even though mAgri services are supposed to empower smallholder farmers it's hard to do so if farmers aren't aware those services or if they do not know how to interact with them. A research study conducted in rural Kenya [WSC⁺16] indicated that novice or low-literate users preferred making voice calls rather than sending text messages due to their limited technological proficiency. Other variations of mAgri services are the use of call centres and video calls to better instruct farmers. Even more advanced, and something developed countries are investing more on, is the mobile web [4] and installable applications [Ava13], these allow infinite possibilities of integration with other devices and technologies and provide a much more sophisticated interaction.

Findings from another research [GWO⁺16] conducted in Kenya involving 56 farmers evaluating an mAgri application that contained SMS, Voice and web-based components indicated that all the interviewed farmers mentioned that the delivery platform (i.e., IVR, USSD, SMS) would determine if they would use the system, being SMS the preferred mode of interaction. Therefore several external factors should be taken into account when developing ICT solutions for farmers, for instance access to electricity, network coverage, users education level, cultural, social and gender constrains [M⁺16]. The choice of technology should be adapted to the users needs, kind

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[3] http://farmerline.co/
[4] https://www.plantvillage.org/

of devices they have access to (see figure 2.2 relating mobile phone type to technologies) and capabilities [GWO$^+$16].
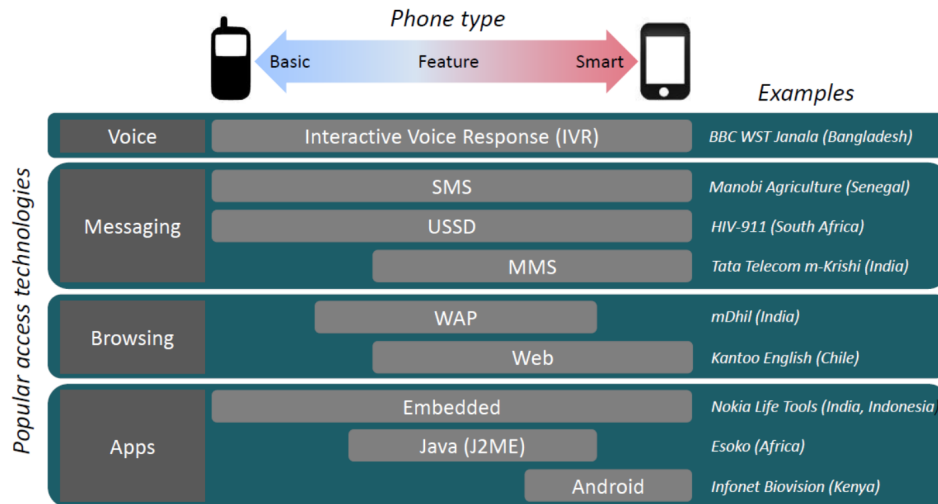
Figure 2.2: Personal mobile devices and delivery technologies [HGWH13]

2.1.1 mAgriculture Solutions

The GSMA mAgri Programme [5] was founded in 2009 and works with the mobile operators, who are members of the GSMA, together with agricultural organizations and development organizations to look at where mobile technology can bring benefits to the agriculture sector. GSMA proposes [Int15b] that mAgri solutions should be divided into three categories:

1. **Agricultural value added services (Agri VAS)** — These consist of machine-to-human interaction and are delivered through SMS, USSR, helplines, interactive voice responses (IVR) and, increasingly, by web and mobile applications. Even though farming is one of the main drivers of the economy in developing countries there's a key challenge that arises, the productivity level of farmers in developing countries is lacking when compared to that of developed countries.

2. **Machine-to-machine (M2M)** — This category is, as the name indicates, related to technology that coordinates multiple machines, devices and appliances connected via communication channels. This category features devices like smartphones or tablets and Precision Agriculture is an example of an application of M2M in agriculture (this concept is covered in detail in section 2.2) [Int15a].

3. **Mobile financial services tailored for the agricultural sector** — This third category consists of solutions in Agri MFS (Mobile financial services), combating farmer's financial

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[5]http://www.gsma.com/mobilefordevelopment/programmes/magri

exclusion. Some farmers in developing countries don't have access to a bank account and they should be able to have loans, savings, insurance.
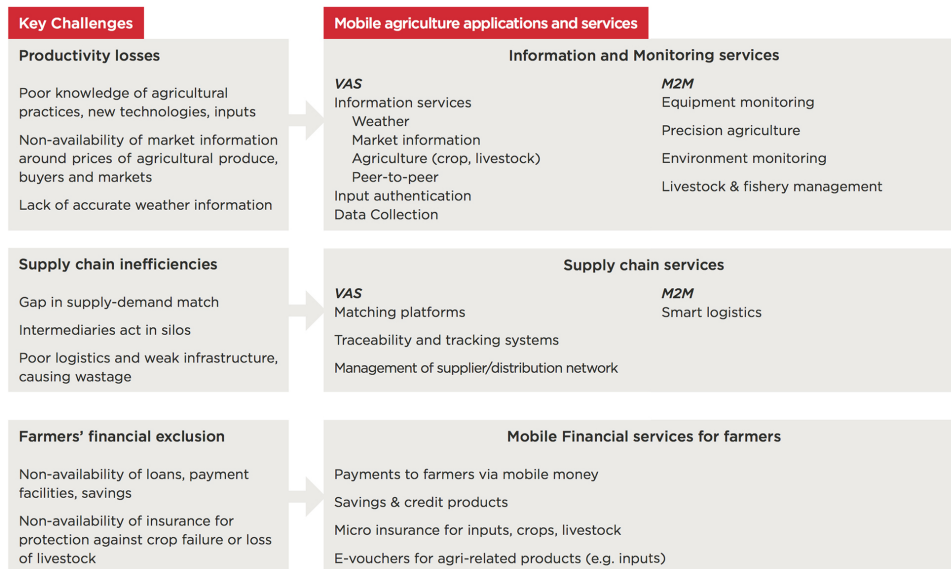
Figure 2.3: mAgri use cases and benefits – the opportunity for mobile [WEU12]

2.1.2 Mobile Applications in the Market

Mobile agriculture applications fall in many different categories. A study published in 2012 by Gary Woodill and Chad Udell from Float Mobile Learning focused on applications (apps) developed for the agriculture industry in Canada and the United States and compiled a list of 60 apps and grouped them in 9 distinct categories, as shown in figure 2.4.

Contrasting with GSMA's mAgri Programme, that is focused in developing mobile solutions to impact smallholder farmers, this report only collected and analysed solutions developed for the Canada and North America's market, therefore, developed regions.

2.1.3 Potencial of mAgri

Nowadays most solutions for mAgri encompass technology that is easy to use and not very sophisticated, using more common phones with a lower price point. The success rate of using Voice/IVR, SMS or USSR protocols in developing countries is higher when compared to rich media, like installable applications, because of constraints like purchasing power and technological proficiency of the users [T+16].

> "The number of potential Agri VAS users using rich media services will increase by 2020, accounting for approximately 60% of total potential VAS users." [T+16]

Rich media services, are the future of mAgri. With declining prices of smartphones in emerging markets [T+16] it'll be possible to produce more sophisticated systems that'll integrate with tools
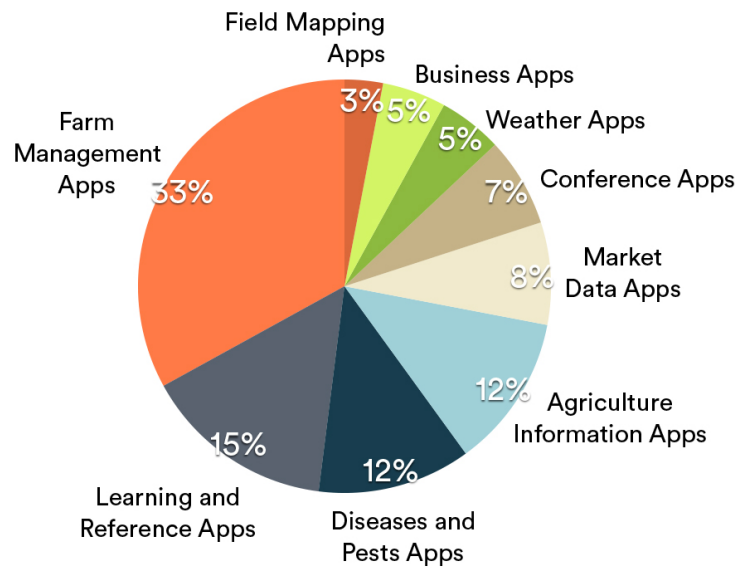
Figure 2.4: Mobile Apps categories of mobile agriculture apps [WEU12]

such as sensors and making it possible for small farm holders to optimize their production and increase their yield.

2.2 Precision Agriculture

The concept of Precision Agriculture, sometimes called Precision Farming, originated in the mid 80s and was made possible by the development of information technology and remote sensing. A traditional management approach to farming would be to perform a particular task, such as harvesting, against a predetermined schedule. Now with PA, by using site-specific knowledge, it is possible to access and control in real-time data on weather, soil, air quality and therefore make smarter decisions and assist farmers in making the right decisions at the right time.

PA provides a way to automate Site-specific management (SSM), which can be defined as "electronic monitoring and control applied to data collection, information processing and decision support for the temporal and spatial allocation of inputs for crop production." [PSLDS97], using information technology (IT). SSM can be described as the idea of doing the right thing, at the right place, at the right time [BLD04].

2.2.1 History and Technologies

The idea of collecting data to inform decision making has been around for a long time, but integrating technology with this process is somewhat recent [Bra]. In the past, the size of farms made possible to work around the problem of within field variability because farmers had the capacity to manually adapt to the temporal and spatial variability of the plot. But as farms became larger and

processes became mechanized, it was necessary to create a solution to combat soil heterogeneity and manage variability of nutrients, seeding rate, weeds and other inputs [Bra].

According to David Franzen and David Mulla's brief review of PA history [Z^+15] this research began in the early 1920s, using as a foundation small fields and resulting in the first published study by Linsley and Bauer, dating back to 1929, that recommended soil sampling to address this problem. This evolved to self-propelled fertilizer application equipment and by 1938 [Salter, 1938] various machines were available to farmers. Following the authors' findings, to process the data generated from sampling required a computational power that at that time was not enough, but nowadays with technological advances in Geographical Information Systems (GIS), it is possible to keep precise information about crops, such as soil type and nutrient levels, providing techniques needed for data visualization and interpretation of particular field locations, with the production of maps [6].

Later in 1993 the introduction of GPS and GPS receivers led to the breakthrough of PA [7]. Previously only available for military uses, GPS was opened for civilian application, allowing to perform unbiased sampling performed in a random order from unusual areas, rather than taking into account specific locations and distances. Nowadays these network of satellites also help with Automated steering systems that help reduce human error [8].

GPS receivers combined with yield monitors and with Variable Rate Technologies (VRT) allowed the monitoring and mapping of yield variations within fields and the ability to apply inputs (seeds, herbicides, pesticides) at varying rates, depending on the exact variations of factors such as soil nutrients, type, among others [9].

2.2.2 Benefits

The obvious benefits of PA are allowing the monitoring and control of various parameters, in real time and making remote accessing possible. Besides these benefits the main ones are increase of profitability, and sustainability.

One of the most relevant benefits is how PA can be a positive factor to the environment, by reducing losses from excess applications due to nutrient imbalances and also reduction in pesticide resistance development. It has been proven that PA, by using site-specific knowledge, should reduce environmental loading, that being by applying fertilizers and pesticides in a more targeted way, only where and when they are needed [BLD04].

Profitability of PA is difficult to predict and we can conclude that because precision farming practices are site-specific, profitability potential is also site-specific [SLD98]. For instance the use of VRT is highly profitable in some areas of the world and when used on certain crops and, in others, it doesn't even cover the costs.

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[6] https://www.gislounge.com/use-gis-agriculture/
[7] http://www.agriprecisione.it/wp-content/uploads/2010/11/general_introduction_to_precision_agriculture.pdf
[8] http://www.gps.gov/applications/agriculture/
[9] http://w3.ufsm.br/projetoaquarius/index.php/en/the-project/precision-agriculture-history

2.2.3 Concerns

Some of the main concerns that come up with the use of PA are the high costs of implementation and keeping up with advancing technology and return on investment. Regarding farm-level data generated by PA, the biggest issues most frequently identified by the users were interpreting the data, privacy, ownership, and accuracy of the data [CLL15].

Several factors such as "cultural perception, infrastructure, institutional constraints, knowledge and technical gaps" [KL15] are also some of the major obstacles to the adoption of PA.

The degree of digital literacy of the end-user makes the use of PA much harder in rural, remote or underdeveloped areas, and therefore, is important to develop PA tools using user centric design approach, with the users' requirements in consideration.

2.2.4 Adoption

Both benefits and concerns of PA will facilitate or inhibit the adoption of ICTs in the agricultural sector.

A literature review [PCPC13] of the drivers of PA technologies adoption, identified the key drivers that affect the intention to adopt tools available for PA management. The review was divided in an ex-post and ex-ante context, being ex-post Latin for "after the fact" and ex-ante, the opposite, meaning "before the event".

Ex-post studies demonstrated the motives or reasons that encouraged and were still encouraging farmers to adopt PA technologies. The most cited parameter was the size of the farm, where the intention to adopt was greater when the size of the farm was bigger. The second most important driver was the adopter's confidence with computers.
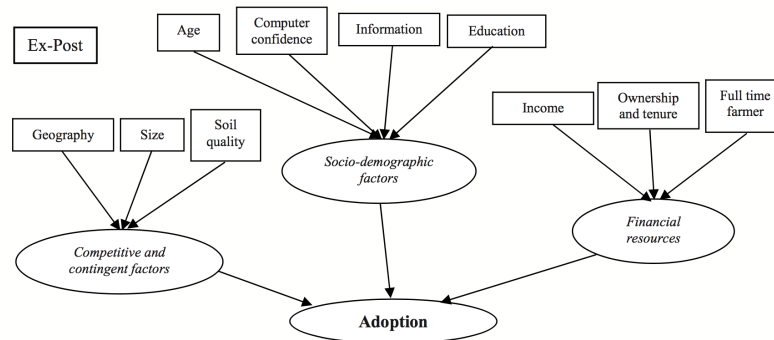
Figure 2.5: Factors affecting attitude to adopt – Ex-Post [PCPC13]

The ex-ante studies were predictive investigations that revealed which drivers could affect the potential user's behaviour before a decision was made to use, or not to use, a new PA technology. They allow the analysis of acceptance of new technology prior to their introduction. These indicated that increasing profitability was the main motivation that stimulated the use of new technology. In the approach of the Technology Acceptance Model (TAM), used to explain the process of adopting new technology, there is a construct named Perceived Usefulness (PU) that relates to

this issue is defined as "the degree to which a person believes that using a particular system would enhance his or her job performance" [Dav89]. Another relevant factor is the Perceived Ease of Use (PEU), "the degree to which a person believes that using a particular system would be free of effort" [Dav89].
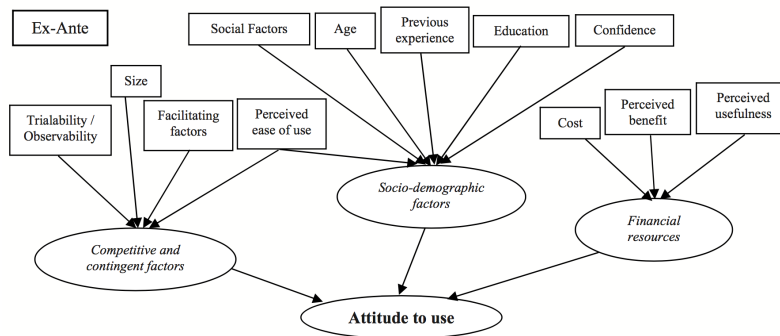
Figure 2.6: Factors affecting attitude to adopt – Ex-Ante [PCPC13]

2.3 Summary

With the use of ICT solutions farmers can nowadays have access to information that will support their decision making process. There are several applications in the market which rely on different choices of technologies to support different user needs. mAgriculture is a research area focused on enhancing rural development by using ICT solutions that provide different functionalities, some rely on SMS or USSD protocols while others rely on more complex systems, such as, installable applications.

Precision Agriculture provides many benefits such as increase of profitability and sustainability, by using site-specific knowledge using sensors and other technologies.

In order to develop software that is going to be adopted and accepted by users it is necessary to design with them at the centre of the process. The next chapter focuses on literature review on the user centred design methodology.

Chapter 3

User-centred Design

There are a number of interaction design methodologies but only a certain number pursue a user-centred philosophy and one of the most widely used is the also known as User-Centred Design (UCD) [AMkP04]. UCD is an approach within the field of HCI (see 3.1.1) that deals with the development of a system always focusing, during the design process, on the wants, needs and limitations of the users. User can be a very broad term, but one of the most obvious interpretations is the person who interacts directly with a product to perform a task. There are many other interpretations, where some include those who test the product, who manage direct users, etc. [HJ93]. Another one may be primary (frequent hands-on users), secondary (occasional users) and tertiary (affected by the system or purchase influencer) users [Eas87]. Stakeholders are "people or organizations who will be affected by the system and who have a direct or indirect influence on the system requirements" [KS98], and that includes end-users, the formal client who orders the product, the development team or others.

According to a partnership between Frog Design Inc. and GSMA, that focused on unlocking the rural market with UCD [Wes14], farmers have a hard time trusting mobile services and relying on them for tips on how to run more efficiently their practice.

> "Only 25% of registered farmers on Mobile Agriculture product use the service more
> than once" [Tse15]

They have a hard time because their livelihood for a season depends on 2 to 3 chances during a whole year to profit from a harvest and if they listen to the wrong advice that can jeopardize their business. UCD is one step to earn that trust, constituting a great methodology to follow when centred around costumers that are harder to reach. Investing in design has been proven to outperform businesses that don't integrate design in their life cycle.

> "Results show that over the last 10 years design-led companies have maintained sig-
> nificant stock market advantage, outperforming the S&P by an extraordinary 228%."
> [Wes14]

UCD is not only about focusing on making products with better usability and user experience, but about innovating and having an impact in the world, creating awareness for the product and

subsequent adoption and making sure that even after deployment the product will continue to be improved.

Gould and Lewis [GL85] state that three principles should be followed in order to lead to a "useful and easy to use computer system":

- **"Early focus on users and tasks"** — studying and observing them and involving the users since the beginning of the design process;

- **"Empirical measurement"** — recording and analysing users' performance and reaction;

- **"Iterative design"** — when problems are encountered, fix them and continue testing.

These principles are timeless and now accepted as the basis for a user-centred approach [PSR15].

3.1 Disciplines surrounding UCD

3.1.1 Human-computer interaction

Human-computer interaction (HCI) is an interdisciplinary field that is defined as "a discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them." [DFAB03]. It has become an umbrella term that encompasses diverse disciplines.

HCI is a subset of usability (see 3.2) and focuses on how humans interact with computing products while UCD is a methodology used to ensure that the products meet the users' needs [Low13].

3.1.2 Ergonomics

The International Ergonomics Association establishes that "Ergonomics is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance." [1]

Ergonomics is traditionally a study of the physical characteristics of interaction [DFAB03], is a field closely related to HCI but distinct, and helps constraining the design of systems based on user performance and the role of the interface in that performance. It goes from how controls are designed to the physical environment in which the interaction takes place.

3.1.3 Interaction Design

Interaction Design (IxD) is about "designing interactive products to support people in their everyday and working lives" [PSR15]. Winograd [DM97] described it as "the design of spaces for

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[1] http://www.iea.cc/whats/

human communication and interaction". IxD encompasses academic disciplines like engineering, informatics, amongst others and also design practices such as graphic design and product design. HCI is an area of study opposed to IxD, a design craft that deals with interaction, not necessarily being specific to computers.

The process of interaction design goes through the identification of user needs, developing alternative designs to fit these, building interactive prototypes that can be communicated and assessed, and evaluating throughout this process what is being built and the user experience it offers.

3.2   Usability and User Experience

Usability

Nowadays it's common to hear the term "user-friendly" to connote ease of use and interaction, but "in reality, different users have different needs, and a system that is "friendly" to one may feel very tedious to another" [Nie94]. Usability is considered by Jakob Nielsen as a multi-dimensional property that refers to how easy interfaces are to use [2] defined by five quality components [Nie94]:

- **Learnability** — a system should be easy to perform basic tasks by a first time user;

- **Efficiency** — once the user has learned the system he should be able to be highly productive;

- **Memorability** — after a period of inactivity a user should be able to pick up easily and re-establish proficiency;

- **Errors** — the system should have a low error-rate and allow users to easily recover if they make errors;

- **Satisfaction** — the system should be pleasant to use.

  > "if the system forces the user to adopt an unacceptable mode of work then it is not usable" [DFAB03]

Users should not only find a system efficient and effective, they should also want to use it, and that comes with the development of interactive products that ensure usability, and most importantly, that measure it.

User Experience

User Experience (UX) is defined by Don Norman and Jakob Nielsen through the sentences: "The first requirement for an exemplary user experience is to meet the exact needs of the customer, without fuss or bother. Next comes simplicity and elegance that produce products that are a joy to own, a joy to use. True user experience goes far beyond giving customers what they say they

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[2]https://www.nngroup.com/articles/usability-101-introduction-to-usability/

want, or providing check-list features. In order to achieve high-quality user experience in a company's offerings there must be a seamless merging of the services of multiple disciplines, including engineering, marketing, graphical and industrial design, and interface design" [NN].

UX and usability should be distinguished, the latter term being a quality attribute of the UI, related to how easy a system is to use, how efficient and so forth. UX is an even broader term, related to how the person feels when using a product. Some examples of those feelings can be excitement, fun or aesthetic pleasure.

3.3 Understanding the user

3.3.1 Problem Space

In order to solve any problem it's necessary to understand the problem space, therefore ask what, why and how [PSR15]. Identifying usability and user experience goals are a part of that process, being those of an existing product, how it can be changed or improved, or those of a new one. Having a good understanding of the problem space can help inform the design space what kind of interface, behaviour and functionality to provide.

3.3.2 Conceptual Models

When designing a system is crucial to, in the early stages, understand and conceptualize the user experience. It's necessary to have a good understanding of the problem space, meaning what you want to create, why and how it will support users in the intended way. A conceptual model is "a high-level description of how a system is organized and operates." [JH02]. It helps to outline what people can do with a product and what concepts are needed to understand in order to interact with it. Thus it includes all concepts exposed to the user and the sequence of operations performed to complete a task.

The better the conceptual model matches the user's existing mental models the better the user experience will be.

3.3.2.1 Metaphors

Metaphors can be used to convey the understanding of how an interface works and help users interaction. They provide a way to teach new concepts and familiarise the user [DFAB03], helping them understand the underlying conceptual model [PSR15]. They should be used with this purpose but sometimes can have negative effects, being important to understand when the use of a metaphor breaks design principles.

3.3.2.2 Interaction types

There are different ways a person interacts with a product and Jenny Preece, Helen Sharp and Yvonne Rogers [PSR15] propose there are four different types of interaction that are not meant to be mutually exclusive nor meant to be definitive.

- **Instructing** — issuing commands using keyboard and function keys and selecting options via menus;

- **Conversing** — interacting with the system as if having a conversation;

- **Direct Manipulation** — interacting with objects in a virtual or physical space by manipulating them;

- **Exploring** — moving through a virtual environment or a physical space.

3.3.3 Mental Models

Mental models can be described as internal constructions of reality made by the mind that it uses to anticipate events, describing the user's view of how things work [Cra43]. The difference between conceptual models and mental models is that conceptual models are "devised as tools for the understanding or teaching of physical systems" [RB88] and mental models are "what people really have in their heads and what guides their use of things" [RB88].

3.3.4 Cognition

Interacting with technology involves a lot of cognitive processes. Cognition can be distinguished between two general modes [Nor93]: Experiential Cognition, a state of mind in which we perceive, act and react to events around us effectively and effortlessly (e.g. driving a car), and Reflective Cognition that involves thinking, comparing, and decision-making (e.g. learning or writing).

3.3.4.1 Cognition Processes

Some of the processes that affect behaviour are:

- **Attention** — Information structure at the interface that better captures user's attention, e.g. use of perceptual boundaries, colour and sound.

- **Perception and recognition** — Perception refers to how information is acquired. Obvious implication is to design representations that are readily perceivable, e.g. text should be legible and icons should be easy to distinguish and read.

- **Memory** — Humans recognize things better than recalling, for instance we're better at remembering images than words. Interfaces should help people remember essential information, promoting recognition rather than recall. Memory involves encoding and then

retrieving of knowledge. Context is important when it comes to memorization, sometimes it can be difficult to recall information encoded in a different context.

- **Reading** — Reading can be quicker than speaking or listening but some users avoid reading [CR87]. It's easier to recognize word shapes and because lower-case words have more distinct shapes, they are quicker to read.

3.4 The Process of Design

According to Alan Dix et al. [DFAB03] there are four main phases plus an iteration loop relating to the design of interaction, represented in Figure 3.1. The first being the "What is wanted" - requirements phase (3.4.1), then the "Analysis" phase (3.4.2), after that the "Design" phase (3.4.3), a loop of "Prototype" - evaluation, iteration and prototyping phase (3.4.4) and finally the "Implement and deploy" phase (3.4.5).
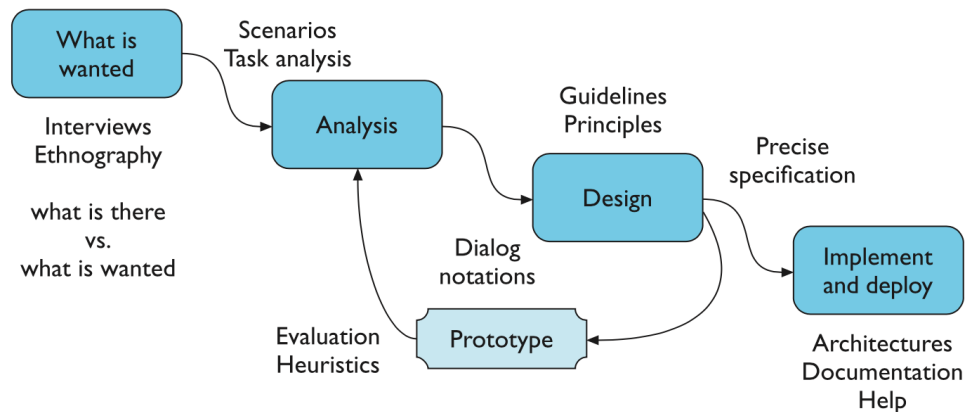
Figure 3.1: Interaction design process [DFAB03]

Life cyle models

It's important to have an understanding about how the design process can fit in the software development process. Life cycle models help show how activities are related to each other, as they are management tools and simplified versions of reality. Traditional models are more adequate for smaller teams, providing a simple process, in contrast to larger systems that need a more detailed and sophisticated model. Here are a few of these models:

- **Waterfall Model** — In software engineering this model was the basis of many development cycle in use nowadays. This traditional view consists of a number of processes in a sequential fashion.

- **Spiral Model** — The Spiral Model [Boe88] takes into account prototyping throughout the design process. The spiral process follows the main stages described in the Waterfall Model, but does it iterating several times, checking and evaluating ideas and enabling risk analysis.

- **The Star Model** — The Star Model [HH89] also features an iterative nature, but with Evaluation at the centre stage of activities. There's also a lack of ordering, making it possible to go from each activity to the other, provided you go through Evaluation in the process. This model is a reflection of empirical studies conducted on how designers went about their work.

3.4.1 Requirements

Requirements are obtained through data gathering and data collection with the help of certain techniques and activities to get a better understanding of users' needs. Conventionally, requirements can be divided into two types, functional and non-functional [Ben10]. According to Benyon functional requirements relate to what the system must do while non-functional requirements are a quality that the system must have and these include for instance usability, aesthetics and cultural acceptability.

3.4.1.1 Research Methods

In order to capture requirements it is important to understand users and conduct user research. To define the research goals, a look should be taken at the existing issues that should be presented as goals. After, these goals should be prioritized and finally rewritten as questions to be answered [GKM12].

There are several methods of design research, and according to Dan Saffer [Saf09] these can be roughly divided into three categories: observations, interviews and activities, where the later one includes subjects performing and self-reporting their activities.

Observations

Observing what people do can be one of the most elucidating methods of design research. Subjects can be observed without any interference from the designer or with interaction, like asking them questions about what they are doing and most importantly, why. Some ways of doing observations include:

- **Fly on the wall** — unobtrusively observing users' behaviour on location [Saf09].

- **Shadowing** — following subjects while they go about their daily activities [Saf09].

- **Undercover agent** — by posing as a normal *person* in an environment it's possible to observe people interacting as they naturally would [Saf09].

- **Ethnography** — a form of observation deriving from anthropology [DFAB03]. Ethnographers observe users in their natural environment, making it possible to analyse the behaviour of individuals in the context of use. This process can take hours to months and the goal of

this observation is to collect data that'll influence the interface design process [SP03]. Compared to other approaches to data gathering Ethnography has the aim of observing without "imposing any a priori structure or framework upon it" [PSR15].

- **Contextual inquiry** — also studies the user in context but it differs from pure ethnographic study due to the intention: "the intention is to understand and to interpret the data gathered, and rather than attempting to take an open-ended view, the investigator acknowledges and challenges her particular focus" [DFAB03]. This is a variation on shadowing because the subjects are asked questions [Saf09];

- **Participatory Design** — in this approach the user comes out of their work situation, either mentally or physically and becomes apart of the design team, entering into the subjective experience of the workplace [DFAB03].

Interviews

Talking to users and hearing their stories can provide a great insight into their experiences and attitudes but can also be dangerous when performed alone because what people say and do are typically very different [Saf09].

- **Directed storytelling** — asking subjects to talk about how they performed an action or their experience in a specific time [Saf09].

- **Focus group** — by assembling a group of representative users in the same group can be helpful to gain a consensus view and to get a better understanding about areas of conflict.

- **Unfocus group** — a variation of Focus groups, developed by IDEO [3] where extreme people passionate about the product/service are brought together allowing to explore the subject from different viewpoints [Saf09].

- **Role playing** — consists of acting out different scenarios by a group or individual in order to perceive how a subject/product/system affects users' emotions and attitudes [Saf09].

- **Extreme-user interviews** — another method created by IDEO [4] requires interviewing people on either extreme of the spectrum, not only the big broad mainstream [Saf09]. This method is used to spark creativity and spur new thinking.

Activities

In design research, doing activities allows designers to go beyond observing and talking to subjects. There are a number of activities proposed by different authors and each can be a great tool

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[3] http://www.ideo.org/
[4] http://www.designkit.org/methods/45

depending on the project and design goals. Collaging [5] and drawing [6] are creative activities, allowing subjects to be more involved by making and explaining their creations and allowing designers to get a better understanding of their values and thought process. Card sorting [7] can also be a quick and easy method of understanding, by having concepts written or printed on cards and the participant arranging, grouping, categorising or organizing them.

Self Reporting

With this approach subjects, without the direct involvement off designers, record their activities and thoughts, allowing them to feel more comfortable and less embarrassed, and then the researcher collects and analyses the findings

- **Journals** — the subject journals particular activities [Saf09].

- **Beeper studies** — the subject is given a beeper and when the designer sets it off during the day the subject records on a journal what they were doing at the time [Saf09].

- **Photo/video journals** — the subject is given a camera and is told to document his life or for instance to take a picture of people in his trust-circle or who influence him [8].

Other data gathering techniques for establishing requirements are the use of questionnaires, studying documentation and researching similar products [PSR15]. Questionnaires can be made up off open-ended or close-ended questions and therefore can be a more qualitative or quantitative technique, depending on what is pretended. Studying documentation is a technique that doesn't require the involvement of stakeholders and can be a good source of data about steps and regulations governing a task. Lastly, researching similar products can be helpful to get a better insight on features and interactions already provided in the market and to prompt requirements.

3.4.2 Analysis

The results from the methods and activities previously referenced need to be analysed in order to bring out key issues that'll guide the Design Phase.

3.4.2.1 Scenarios

According to Alan Dix et al. [DFAB03] Scenarios are stories or narratives of interaction and they're perhaps the simplest design representation. They can be very powerful and can go from a simple description to a full on script describing the situation or context of interaction. Scenarios can also be augmented by sketches, storyboards or other mock-ups and force the developing team to act out potential patterns of use and to anticipate possible problems that could be encountered

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[5] http://www.designkit.org/methods/25
[6] http://www.designkit.org/methods/49
[7] http://www.designkit.org/methods/24
[8] http://www.designkit.org/methods/65

later on. There are other applications for scenarios, for instance telling stories in a natural way allows stakeholders to get a better understanding of users, with the use of non-technical vocabulary and phrasing, and be more participative in the development process [PSR15].

> "The basic argument behind scenario-based methods is that descriptions of people using technology are essential in discussing and analysing how the technology is (or could be) used to reshape their activities. A secondary advantage is that scenario descriptions can be created before a system is built and its impacts felt." [RC01]

Rosson and Carroll (2002) [RC01] explain an approach that illustrates the use of scenarios within a usability engineering framework. Distinct types of scenarios are illustrated in Fig. 3.2, showing:

- **Problem Scenarios** — these tell the story about how users currently engage in their activities and enumerate what features of the current situation have an important consequence. They do not necessarily "emphasize problematic aspects of current practices, but rather [...] describe activities in the problem domain." [9];

- **Activity Scenarios** — after the staring point provided by problem scenarios, activity scenarios are related to how the user could possibly be doing their activities, "maintaining or even enhancing the positive consequences for the actors while minimizing or removing the negatives" [RC12].

- **Information and Interaction Design Scenarios** — "After completing the claims analysis, the goal of information design is to specify representations of a task's objects and actions that will help users perceive, interpret, and make sense of what is happening. The goal of interaction design is to specify the mechanisms for accessing and manipulating the task information and activities." [10]

3.4.2.2 Personas

Related to scenarios it is also possible to define personas. A persona is an invented person used to represent a type of user inserted in a scenario. Assigning to each persona a name, face, personality and possibly other information, allows to talk concretely about a potential end-user. These can be very helpful. The difference between Scenarios and Personas is that the first one describes the use of a product or an activity to achieve a goal, while the latter characterizes a typical user, defining who the story is about, their main motivations, goals and pain points (see Figure 3.3).

3.4.2.3 Task Analysis

Task Analysis can contribute to the statement of requirements when creating a new system or can help in the production of training materials and documentation when existing systems are analysed. Alan Dix et al. [DFAB03] describe three different approaches to task analysis:

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[9] http://ldt.stanford.edu/~gimiller/Scenario-Based/ProblemScen.htm
[10] http://ldt.stanford.edu/~gimiller/Scenario-Based/Infor-InteractDesign.htm
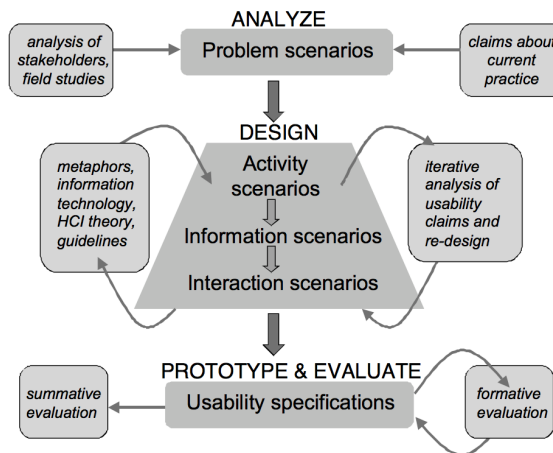
Figure 3.2: Overview of scenario-based design (SBD) framework [RC12]
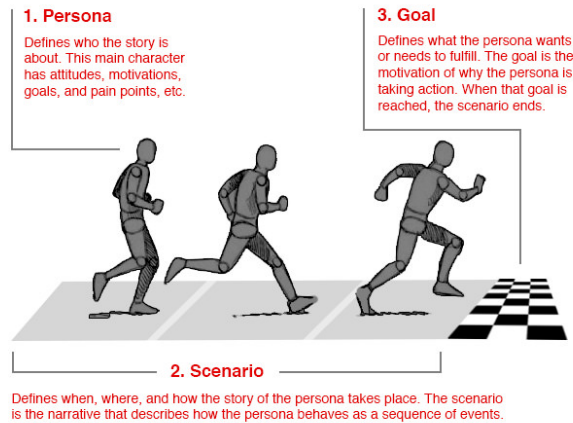
Figure 3.3: Relationship between Scenario and Persona [11]

- **Task decomposition** — "which looks at the way a task is split into subtasks, and the order in which these are performed". Hierarchical task analysis (HTA) is an technique that provides an understanding of the tasks users need to perform to achieve a certain goal and can be recorded in a tree diagram or a textual outline format (see Figure 3.4).
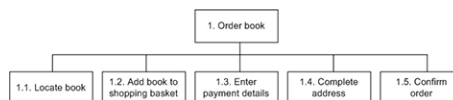
Figure 3.4: Hierarchical task analysis example for ordering a book [12]

- **Knowledge-based techniques** — "which look at what users need to know about the objects and actions involved in a task, and how that knowledge is organized". Through the creation of taxonomies about the object used during a task and the actions performed against it it's possible to get a better understanding of the knowledge needed to perform a task (see Figure 3.5).

```
motor controls
        steering       steering wheel, indicators
        engine/speed
                direct         ignition, accelerator, foot brake
                gearing        clutch, gear stick
        lights
                external       headlights, hazard lights
                internal       courtesy light
        wash/wipe
                wipers         front wipers, rear wipers
                washers        front washers, rear washers
        heating        temperature control, air direction, fan, rear screen heater
        parking        hand brake, door lock
        radio
                numerous!
```

Figure 3.5: Example taxonomic structure of car controls [DFAB03]

- **Entity–relation-based analysis** — "is an object-based approach where the emphasis is on identifying the actors and objects, the relationships between them and the actions they perform" (see Figure 3.6).

Object Pump3 **simple** – *irrigation pump*
Attributes:
status: on/off/faulty
capacity: 100 litres/minute

Figure 3.6: Example listing of some of the attributes of each objects [DFAB03]

3.4.3   Design

After gathering requirements and analysing them it's time to design. This process can be guided by a set of abstract and more specific design rules. Principles are the most abstract, "providing generic knowledge about good design" [DFAB03] and standards and guidelines are more specific, having standards the highest authority. Heuristics and golden rules help design principles and advice to be assimilated by the designer.

3.4.3.1   Design Principles

Design Principles are abstractions created for designers to think about different aspects of design [Nor13]. Some of the most common ones are:

- **Visibility** — The more visible a feature is the more likely the user will be able to know what to do.

- **Feedback** — Information should be sent back to the user to make him aware of what action was performed and what was accomplished, that being with sound, highlighting, animation or a combination of these for instance.

- **Constraints** — Constraints are important to restrict possible actions and help preventing the user of selecting incorrect options.

- **Mapping** — An example of good mapping is the relation between the up and down arrows on the keyboard having the effect of the up and down movement of the cursor. It's also important to take into account the mapping of the relative position of controls.

- **Consistency** — Interfaces designed to have similar operations should use similar elements for similar tasks, making the system easier to use.

- **Affordance** — Is used to refer to an attribute of an object that allows people to know how to use it.

3.4.3.2 Standards

The International Organization for Standardization (ISO) has developed standards for HCI and usability. ISO 9241 is a standard relating to "Ergonomics of Human-System Interaction", it first appeared in the 1980s and nowadays covers the best practices or definitions from Software Ergonomics to Workplace Ergonomics [13]. "ISO 9241-11: Guidance on Usability" defines usability as "The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" [14]. This standard emphasizes that usability is dependent on the context of use, it includes an explanation on how to specify and evaluate the usability of a product and on how to measure user satisfaction and performance.

3.4.3.3 Guidelines

There is a vast number of published guidelines for interactive system design, and we can see that the more abstract the guideline is the more it resembles a design principle. Also the more specific the guideline is, the more it suits detailed design [DFAB03]. Specifically for android development, developers are provided with a set of Material Design guidelines [15] that account for motion, style, layout and a number of aspects that help guiding designers.

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[13]http://www.uxbooth.com/articles/what-on-earth-is-iso-9241/
[14]https://www.iso.org/obp/ui/#iso:std:iso:ts:20282:-2:ed-2:v1:en
[15]https://material.io/

3.4.3.4 Golden Rules and Heuristics

Design rules provide a simpler way for designers to commit and track down guidelines and principles [DFAB03]. Golden rules and heuristics can be used during the design phase or during evaluation, and sometimes in both.

Shneiderman's Eight Golden Rules of Interface Design

Shneiderman's eight golden rules are an example of key principles of interface design that can be applied both during the design and the evaluation phases.

1. "*Strive for consistency* in action sequences, layout, terminology, command use and so on."

2. "*Enable frequent users to use shortcuts*, such as abbreviations, special key sequences and macros, to perform regular, familiar actions more quickly."

3. "*Offer informative feedback* for every user action, at a level appropriate to the magnitude of the action."

4. "*Design dialogs to yield closure* so that the user knows when they have completed a task."

5. "*Offer error prevention and simple error handling* so that, ideally, users are prevented from making mistakes and, if they do, they are offered clear and informative instructions to enable them to recover."

6. "*Permit easy reversal of actions* in order to relieve anxiety and encourage exploration, since the user knows that he can always return to the previous state."

7. "*Support internal locus of control* so that the user is in control of the system, which responds to his actions."

8. "*Reduce short-term memory load* by keeping displays simple, consolidating multiple page displays and providing time for learning action sequences."

Norman's Seven Principles for Transforming Difficult Tasks into Simple Ones

In the book "The Design of Everyday Things" [Nor11] Norman summarizes UCD using the following principles:

1. "Use both knowledge in the world and knowledge in the head."

2. "Simplify the structure of tasks."

3. "Make things visible: bridge the gulfs of Execution and Evaluation."

4. "Get the mappings right."

5. "Exploit the power of constraints, both natural and artificial."

6. "Design for error."

7. "When all else fails, standardize."

3.4.4 Evaluation, Iteration and Prototyping

3.4.4.1 Prototyping

In order to test the system that is going to be developed, drafts are created with different levels of complexity and interaction. These can be divided in two main categories:

- **Low Fidelity Prototypes** — enable a fast way to test prototypes due to their low complexity, and "range from a series of hand-drawn mock-ups to printouts"[Pro]. They provide limited interaction but allow to quickly create alternate versions and for users to easily suggest changes.

- **High Fidelity Prototypes** — are much more realistic when it comes to interaction and because they are more robust they are "much more effective in collecting true human performance data" [Pro].

3.4.4.2 Evaluation

After gathering the system's requirements it's time to test them to ensure they behave as expected by the users. Evaluation should occur during the design life cycle, making iterative redesign possible.

Taking time and money to invest in making more usable products can make traditional managers and engineers sceptical, but there are many papers with evidence supporting that usability testing can pay off [BM05]. Economic analyses showed not only the benefits of spending money in usability, concerning costs reduction, client's satisfaction and user efficiency and productivity [Kar94], but also the improvement in productivity when designers kept usability in mind since the beginning of the design process [Lan95].

Evaluation through expert analysis
It can be difficult to evaluate a design from an incomplete design or prototype and it can be costly and time consuming to conduct usability testing with users. A great complement to tests that require user involvement is conducting tests with experts. The goal of these tests are to detect cognitive principles that are violated and also to ignore accepted empirical results. Different evaluation approaches and methods can be combined to achieve better results.

Some of the methods of evaluation used are:

- **Cognitive walk-through** — is task-specific and is used to identify how easy it is for new users to accomplish tasks in the system.

- **Heuristic Evaluation** — heuristics are "broad rules of thumb and not specific usability guidelines" [Nie95]. The most popular being the 10 Usability heuristics developed by Jakob Nielsen. These resulted in a study of 249 usability problems.

- **Model-based Evaluation**

  - **GOMS** — the GOMS model "predicts user performance with a particular interface and can be used to filter particular design options" [DFAB03]: GOMS stands for Goals (eg. send an email), Operators (eg. double click), Methods (recalling what to do/how to do) and Selection Rules (deciding which method to use to achieve the goal).

  - **Keystroke-Level Model** — predicts how long it takes for an expert user to perform and accomplish a routine task without any errors.

  - **Fitt's Law** — Fitts' Law [Fit54] "predicts the time it takes to reach a target using a pointing device" [PSR15].

- **Using previous studies in evaluation** — a final approach is to support or refute aspects of the design based on previous studies by reviewing relevant literature based on the design under consideration [DFAB03].

Evaluation though user participation

While the previous approaches centred around experts, this approach centres around the user.

- **Styles of evaluation**

  - **Laboratory studies** — done in a controlled environment, user's are asked to perform tasks, data is recorded on video or key presses are logged. User satisfaction is evaluated using questionnaires and interview.

  - **Field studies** — are performed in a natural setting, to get a better understanding of how user's behave in the natural context of product use. Observation, interviews and surveys are some of the methods used.

It's important to emphasize the constant iterative development needed, from prototyping, to evaluating that prototype, to circling back to the Analysis phase, in order to achieve a product that truly fits users' needs and expectations.

3.4.5 Implementation and deployment

This is the final phase, after the final design has been created it's time to implement and deploy, involving writing code, perhaps making hardware, writing documentation and manuals [DFAB03]. This doesn't mean the product can not continue to evolve and adapt in the future.

3.5 Summary

User-centred design is a methodology that focuses on the users' wants, needs and limitations when developing a system. There are many disciplines connected to this approach, such as, HCI, ergonomics and interaction design. The interaction design process calls for collecting data about what is wanted, analysing that data using different methods, studying design principles and guidelines to inform concrete designs, iteratively creating and testing prototypes with users and finally implementing and deploy the product. This chapter helped to inform the methodology followed during this study, that is described in the next chapter 4.

Chapter 4

Methodology

The purpose of this research is to come up with a mobile solution, while having farmers at the centre of the design cycle.

The previous chapters introduced literacy relating to ICT in Agriculture and UCD, both crucial to guide the following research methodology. As such, the following phases presented are based on the process of design presented in 3.4.

As previously mentioned in chapter 2 there are various types of mAgri solutions, from relying on SMS or USSD protocols to more complex ones, such as web and installable applications. In this study, the choice of technology was requested by Fraunhofer AICOS. It should be an android installable app, because of the interest in researching a solution with a higher level of interaction.

4.1 Phase One - Requirements gathering

The first phase, as described in the previous chapter (see 3.4.1), encompasses various methods and activities to gather requirements.

4.1.1 Market Analysis

Different users and stakeholders are crucial to this phase, but due to a delay in getting in contact with important organizations and associations, that would be the bridge between the research team and farmers working in the field. The first step of this phase was researching what the market already offered in regards to Agriculture Apps. As mentioned in section 2.1.2, a study developed by Gary Woodill and Chad Udell dating back to 2012 pooled and categorized mobile agriculture applications existing in the market to that date. This study is considered outdated nowadays and also was restrictive, only including solutions created towards the Canada and United States markets. To get a better understanding of what is offered nowadays to the general public a new updated study was made on agriculture apps in different categories, such as, Learning and Reference Apps, Farm Management Apps, Diseases and Pests Apps and others (presented in Appendix A), gathering applications available up until March of 2017 on the Google Play Store. The sample analysed in this updated study includes 33 mobile android applications and that

sample was selected by: analysing the most popular apps in different categories of mAgri. The categories selected are the ones referenced in the outdated study, minus the category "Conference Apps", because it was not relevant to this study. The sampling was made to include apps from different locations, supporting different languages and ranging from multiple features, in different categories, to single purpose apps. This allowed for a diverse sample and for a broader view of what is available in the market nowadays.

After collecting various data about each app, such as: number of installs, rating, age, supported languages, source location, and some others, it was also important to assign to each app the categories that best fit the functionalities marketed or provided by the developer. Due to the difficulty found assigning this categories, because the apps usually provided multiple functionalities, and sometimes cross-cutting ones, various professionals with distinct backgrounds in areas such as Design, HCI and Software Engineer participated in an activity where they would assign different features to "super-categories" (see Fig. 4.1). A more in-depth report on the activity is provided in Appendix B.

Figure 4.1: Categorizing activity

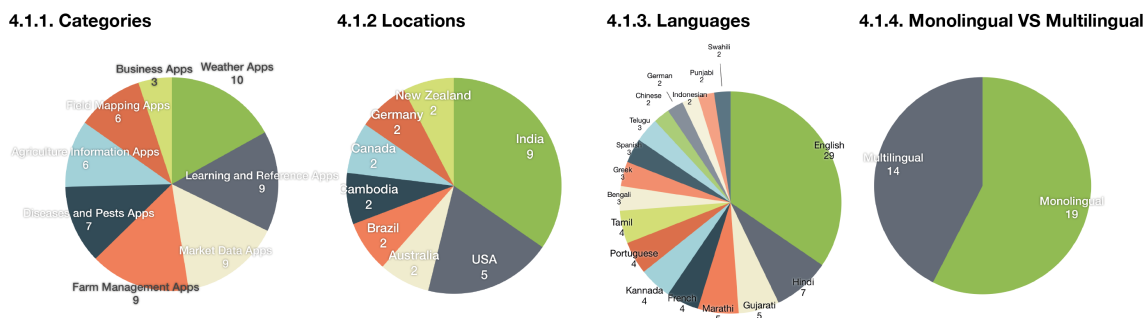Here are some relevant findings from the study:

Figure 4.2: Findings of Market Analysis

The most popular categories are Weather Apps, Farm Management Apps, Market Data Apps and Learning and Reference Apps. By far the most common location is India followed by the

USA. Regarding languages, English is predominant, being present in 29 out of 33 apps and more apps are monolingual than multilingual.

4.1.2 Research sample

This research was performed in Portugal and because of the need to involve the potential end-users in the design process the research sample consists of farmers in rural areas of Portugal.

A study performed in 2013 by the Statistics Portugal institution [INE13, INE15] indicates that agricultural producers in Portugal are the oldest of the the European Union (EU), with more than 52% of them being aged 65 years old or more. The vast majority (70%) only has basic qualifications and only practical agricultural experience. Little of them live exclusively from farming, supplementing their income with retirement pensions.

Another important factor to take into consideration when looking at mAgri solutions for different areas of the world, specially in developing countries or rural areas, is the adoption rate of smartphones in that location.

The Google Consumer Barometer Report [1] points to an increase in the adoption of smartphones in Portugal over the past 5 years, with a 59% rate in 2016 as illustrated in Fig. 4.3, compared for instance to 33% in India in 2015 and 74% in the United Kingdom in 2016. With a sample size n=1,000 in each country except India (n=4,000) the target population consisted of nationally representative total population (online & offline) aged 16 years old or more. Survey data was collected by TNS Infratest via telephone with a dual-frame approach (landlines and mobile phone numbers) [2].

Another study conducted by Marktest indicates that the penetration rate of smartphones in Portugal has grown over 89% since April of 2013. Smartphones exceeded feature phones back in October of 2014, counting as of February of 2016 with 68% of the total number of phone users, as illustrated in Fig. 4.3. This study was composed of a sample of individuals aged 10 or more, residing in Portugal and in the Autonomous Regions of Madeira and Azores, collecting 1250 interviews monthly, 1000 from homes with a landline telephone and 250 from households with a mobile service, without wireline voice traffic.

Agriculture encompasses various types of farming and in order to collect requirements from real farmers it was necessary to focus on a specific area of agriculture instead of researching within the large scope of Agriculture. Since this study was conducted focusing in rural areas of Portugal it was relevant to focus on an agricultural activity that would be prevalent in these areas. When it comes to the size of agricultural holdings, according to an agricultural census "with the exception of farms with farm type "Various crops and livestock combined" (14.7%), holdings specialised in vineyards are the most common in Portugal" [3]. Therefore the scope of the study went from Agriculture in general to Viticulture in the Douro region, which has a low degree of urbanization, as illustrated in Fig. 4.4.

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[1] https://www.consumerbarometer.com/en/
[2] https://www.consumerbarometer.com/en/about/
[3] http://ec.europa.eu/eurostat

(a) Google Consumer Barometer - Percentage of people who use a smartphone in Portugal

(b) Marktest study of Smartphone adoption in Portugal
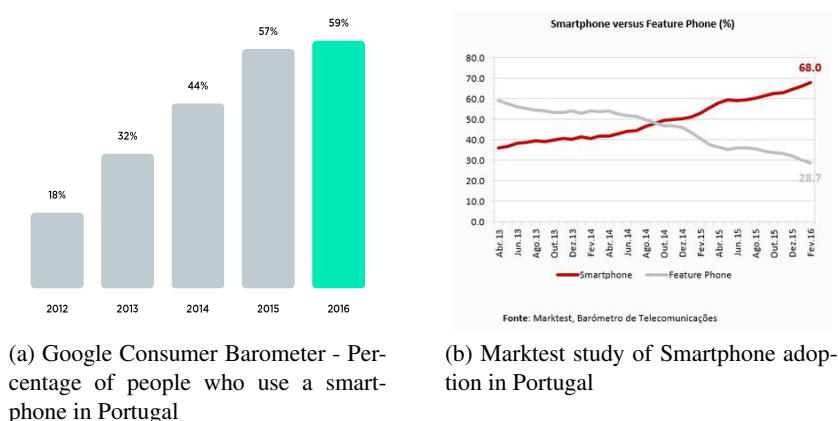
Figure 4.3: Smartphone adoption in Portugal
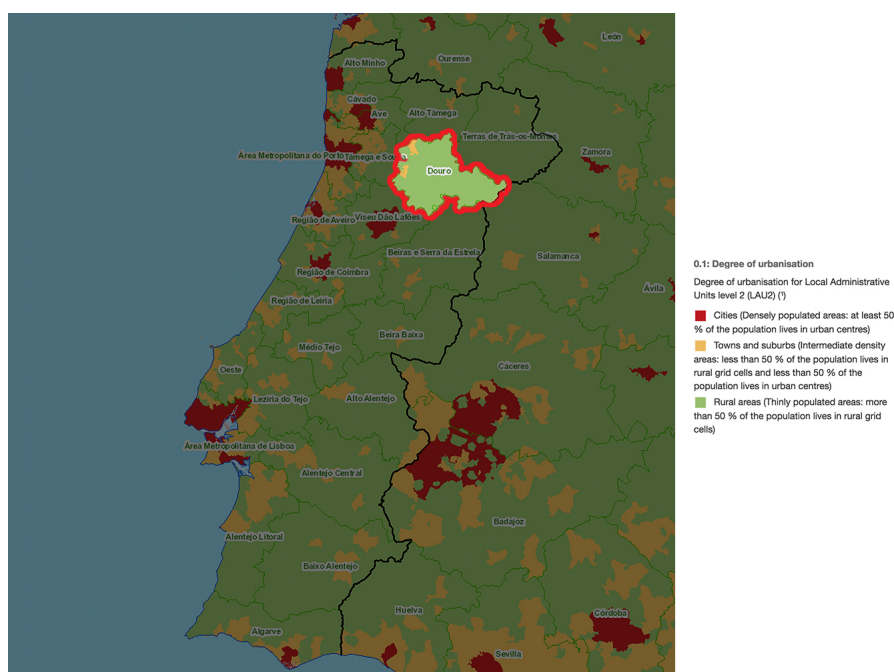
Figure 4.4: Degree of Urbanization - *Douro* Region [4]

The Douro wine region was demarcated because of the need to regulate the sector and sales of Port Wine [5], originating the Demarcated Douro Region (DDR), that is subdivided in three sub-regions, Lower Corgo, Upper Corgo and Upper Douro. According to the latest data provided by IVDP (Instituto dos Vinhos do Douro e Porto) these three regions have a total area of approximately 250.000 hectares, with 43.655 hectares dedicated to vineyards [6]. Approxitamely 21.432

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[4] http://ec.europa.eu/eurostat/statistical-atlas/gis/viewer/?config=RYB-2016.
json&mids=2,8,9,12,2013-3-NAMES,CNTR-OVL&o=1,0.7,1,1,1,0.7&center=38.10049,-3.
19915,6&ch=10,11,34,51,58,70,89&

[5] https://www.ivdp.pt/en/docs/douro_en.pdf

[6] https://www.ivdp.pt/estatisticas_novo2.php

winegrowers, each owning an average of 2 hectare of land, work in these regions. Therefore small winegrowers play a big role in the production of wine in the Douro region. This has been changing over the years, with the area per producer increasing since 2010, as illustrated in the graph in Fig. 4.5.
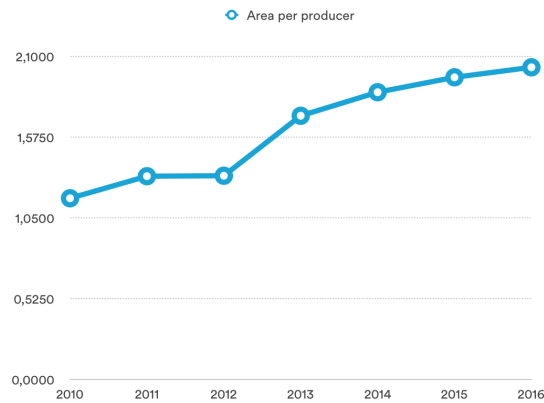
Figure 4.5: Area per Producer

More statistical data about Portugal and the Douro region can be found in Appendix C.

4.1.3   Research Methods

As mentioned above, Viticulture was the chosen area of focus for this study, and it deals with the production of grapes with the cultivation of vineyards, and usually, especially in this area of the country, follows more traditional methods due to the impossibility of mechanisation, because of the difficult accessibility present in the area or due to a need to keep the heritage of the process alive.

The methods used to capture requirements were chosen from the ones mentioned in the previous chapter (see 3.4.1.1). This choice depended on time constrains, availability from the people involved and also on which methods would provide a better insight on the viticulture activity, because none of the research team members was an expert on this field.

4.1.3.1   Interviews

Contact was made with three different entities directly involved in the wine growing business, each with different roles and goals. Interviews were conducted with winegrowers and relevant stakeholders, such as winemakers, lab and field technicians, cooperative and association members, thus providing insight into the main problems encountered, by different people, with different roles.

On total seven interviews were conducted, some on-site, while others went via skype or phone call. These interviews helped to identify key-areas of opportunity while also helping to educate the research team on the field of viticulture.

One interview consisted of a Focus group activity, with three winegrowers, one technician and two cooperative representatives as participants. This activity was important to cross opinions and find problem areas from different points of view.

The interviews began as more unstructured interviews and with the advances of the project they transformed into more semi-structured and structured, being composed of both open and close ended questions, due to the increase in specificity in relation to the problems encountered and the matters addressed. An example script can be found in Appendix D.

4.1.3.2 Observations

Field visits are fundamental to better understand the needs of the winegrowers and associated stakeholders, the problems they encounter, how they solve them and how technology may facilitate that problem solving.

Two field visits were conducted, one to a smaller winegrower and one to a medium/large winegrower, making it possible to see different realities of the same type of agriculture.

It was clear to see, during both visits, that the access to the plots is tricky for winegrowers, especially for an older person, and for machinery. The terrains have to be adapted for tractors and other machines to access it, as can be seen in Fig. 4.6. The conditions under which the farmer's daily tasks are done can then be very difficult, especially during warmer days, due to the dry and warm climate of the region.

Figure 4.6: Vineyards on steep slopes and terraces

It is important to highlight that the visits were conducted at the beginning of the year, in April, making it hard to get an understanding of the whole winegrowing cycle. During this time of year winegrowers are preparing for the flowering phase and being less active when compared to the months anticipating the harvest time.
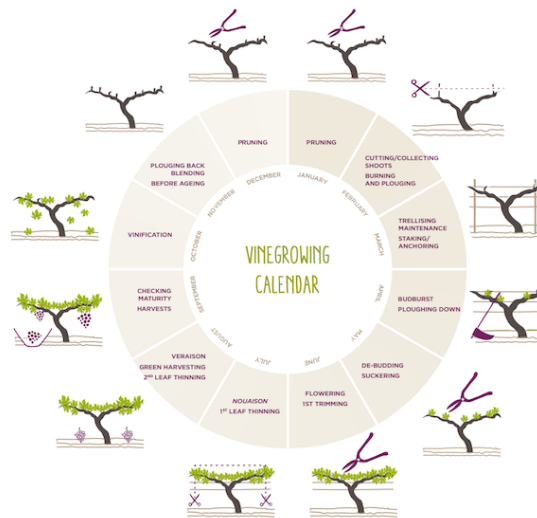
Figure 4.7: Winegrowing Calendar [7]

Due to the difficulty of having an insight into all the activities winegrowing requires, methods that only allowed observing users were not viable, therefore the Contextual Inquiry technique allowed to, not only observe users on their natural setting, but also to conduct an interview in the field and guide the conversation topic to relevant topics that were previously mentioned in interviews.

4.1.4 Findings

Collecting the findings from interviews and visits resulted in three main themes that could be considered areas of opportunity:

- **Forecasting the harvesting potential** — predicting the quantity of grape/harvesting potential is useful for a better management of resources, aiding in better decision making of when to harvest and how long it will take. Nowadays one of the methods for production forecast, performed in May, is the Pollen Method. "This model involves the capture and analysis of the amount of pollen released by grapevines in three locations representative of the three subregions of the Demarcated Douro Region (RDD), thus integrating climatic and phenological data." [8] This method is sometimes too precocious and can result, at a later stage, in very different outcomes.

- **Ripening control** — besides quantity, the quality of the grapes is crucial to achieve a high quality wine. This also influences when the harvest takes place and this analysis is made by collecting grape berries and testing in a lab a list of parameters, such as: ph level, acidity,

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[7]http://www.evineyardapp.com/blog/wp-content/uploads/2016/02/vineyard-calendar.png
[8]http://www.advid.pt/imagens/boletins/13753484584274.pdf

among others. The process of collecting samples, labelling them, taking them to the lab, performing tests and reporting the results can sometimes not be very organized, be laborious and time consuming.

- **Pests and Diseases Prevention and Control** — This is an issue that affects both the quantity and quality of grapes. Pests and Diseases may generate very large losses, not only for that year's harvest but also for future harvests. An overview of the main pests and diseases that attack the vineyard in the Douro region is provided in Appendix E. Prevention and Control are conducted depending on the pest or disease in question. Usually risk assessment is performed, for pests, through the use of traps (traps examples illustrated in Fig. 4.8) and for diseases depending on the knowledge about its biology and epidemiology. Control is conducted through cultural precautions and/or chemical control.

Figure 4.8: Two types of traps: Yellow sticky trap and Pheromone trap

From these three opportunities "Forecasting the harvest potential" was considered the less valued to develop an ICT solution for, because the level of interaction between the farmer and the application would be low considering the methodology followed nowadays, therefore two themes remained.

In order to chose which opportunity of design would be further investigated and the area our solution would tackle, a brainstorming activity was conducted, with the same participants from the activity mentioned in 4.1.1. During this activity (see Fig. 4.9) an introduction and presentation of the context of the project were presented and in order to provide a better understanding of data gathered to that date, personas and scenarios were also presented (see Appendix G). The purpose of the brainstorming activity was also to generate concepts and ideas for a mobile app and resulted in possible features for these two areas of opportunity. It was established that the main area of opportunity was "Pests and Diseases Prevention and Control" because it would allow to better study interaction of the winegrower, contrary to "Ripening control" that would result in an application mostly used in a more controlled environment, inside a laboratory, and by people that could be easily guided on how to interact with the application. A more detailed report on the activity can be found in Appendix F.
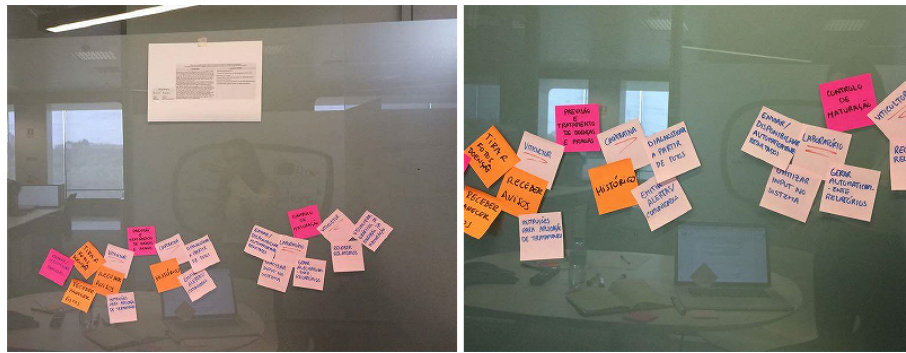
Figure 4.9: Brainstorming activity

Concerns

Some of the main concerns relating to "Pests and Diseases Prevention and Control" are:

- **Prevention and treatment can be instinctive** — usually less educated users go for what they know and their experience tells them, making sometimes decisions that can be fatal to their crops. One example found during an interview was of how winegrowers sometimes choose pesticides because the name of the product is long and difficult to pronounce and not because it was more effective.

- **Late treatment can be devastating** — timing is crucial when trying to attack pests and treat diseases. Sometimes winegrowers perform treatment when it is more favourable to them. Some perform treatment on the weekend because they can get family to help and save money on hiring people. Another factor that influences the timing of the treatment is the weather, if it is too hot people treat during the late afternoon and in the early morning. If it is raining heavily treatment has to be postponed.

- **Selective prevention/treatment can be difficult** — inside the same plot many factors influence how a disease progresses and how pests attack, some factors being: altitude, sun exposure, proximity to a body of water, the planted grape variety, among others. Therefore it is important for treatment and evolution tracking of the vineyard to be done selectively, meaning, treating spots instead of the whole plot.

Goals

Summarizing, when it comes to pests and diseases prevention and control it is important to get all the information needed to know how, when and where to act, in order to prevent losses. Besides this, some other goals were mentioned by different stakeholders:

- **Increase farmers' productivity** — by reducing the amount of paper work and by computerising, organizing and structuring information in one place. Also, as pointed out before (see 4.1.3.2) because the access and work on the field can be exhausting (due to terrain or

weather), it could be valuable to maximize the amount of work the farmer could do remotely, reducing on-site work.

- **Facilitate access to information (weather, warnings)** — currently the Regional Direction of Agriculture and Fisheries of the North is responsible of sending out warnings about various pests and diseases to farmers in the *Douro* and *Minho* region. The transmission can be made by mail (with a fee of 15 euros), e-mail or by displaying the printed documents in the Parish Council, captured on the field in Fig. 4.10, seeming to be the preferred method by small farmers with low levels of literacy.

Figure 4.10: Warning displayed at the Parish Council

- **Educate about pests and diseases** — in order to better educate farmers it is important to provide educational content about pests and diseases in order to combat some concerns that arose previously.

- **Encourage younger population** — another possible goal with the creation of mobile solutions for this field can be to encourage younger people to enter into the winegrowing activity/business.

- **Bridge and facilitate the communication between the farmer and an expert** — most winegrowers, being small or medium/large producers, rely on experts' opinions for decision making, making it relevant to provide a communication channel between these two players.

There is a vast number of pests and diseases that affect the DDR but, for time management purposes, the analysis phase will be focused on the prevention and control of the grapevine moth, which is considered the " main vineyard pest in the Demarcated Douro Region"[Car12].

The grapevine moth, *Lobesia botrana*, causes direct damage, by perforating the flower buds and clusters, and by nibbling the berries, but also causes indirect damage by making the vineyard more vulnerable to diseases, such as the grey rot.[Car12]

A series of technical notes published by ADVID - *Associação para o Desenvolvimento da Viticultura Duriense*[Car12] collects in one publication practical guidelines to support decision-making when it comes to dealing with the grapevine moth. There are two main tasks winegrowers carry out when it comes to prevention and control of this pest:

- **Risk Assessment** — begins with the placement of pheromone traps, that capture adults (see Fig. 4.11a), enabling to keep track of the flight curve of the moth, "for determining the periods in which the risk assessment for each generation should be concentrated"[CA06].

The first adults usually appear around mid-March and each generation of the *Lobesia botrana* has a different impact on the vineyard (see Fig. 4.12). Depending on the generation, the risk assessment requires different tasks:

- **1st generation** — winegrowers estimate damages from trace bloom, based on nests per cluster. They need to look out for signs of the larvae, such as flower buds spun together and silk threads;

- **2nd generation** — if/when the number of captured adults caught in traps intensifies up to one week after the peak, the winegrower needs to look for viable eggs or perforations on clusters;

- **3rd generation** — as proposed for the 2nd generation, for the 3rd the same methodology should be followed. If the adult count is high that is when risk assessment should be performed.

(a) Adult *Lobesia botrana*   (b) Viable egg
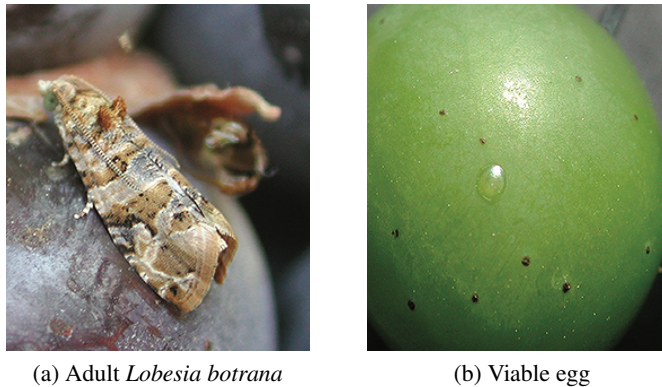
Figure 4.11: Morphology of the Grapevine - Adult and Egg [Car12]

Figure 4.12: Damages of 1st, 2nd and 3rd Generation [Car12]

This methodology requires visual observation for all the stages and requires the count of moth adults in traps and of viable eggs, while also requiring to keep track of all these data, in order to monitor the pest.

- **Pest Management** — which is done in one of three ways:

  - **Cultural precautions** — such as pruning and training the vine, dusting with sulphur, road dust or lime, leaf removal, etc.

  - **Chemical Control** — this control depends on various factors, such as the pest's biological cycle, in order to choose the active ingredient of the pesticide accordingly, the period in which the treatment is effective, the withdrawal period between applications, especially when near the harvest time, and the application of the spray for an effective treatment.

  - **Mating Disruption** — another method to protect against the grapevine moth consists of placing pheromone dispensers (see Fig. 4.13) and with the saturation of the sexual pheromone of *Lobesia botrana* disturbing the encounters between males and females, preventing mating and egg-laying and consequently the damages provoked by the resulting larvae.

Figure 4.13: Pheromone dispenser [9]

As seen above, during the requirements phase, the scope of this study changed, as illustrated in Fig. 4.14.

4.2   Phase Two - Analysis

After gathering requirements it is time to transform the gathered data, from interviews and observation, into data that'll guide the design of the system.

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[9]http://greenchina.sensocomum.pt/Xfiles/images/site14Pimage350.gif
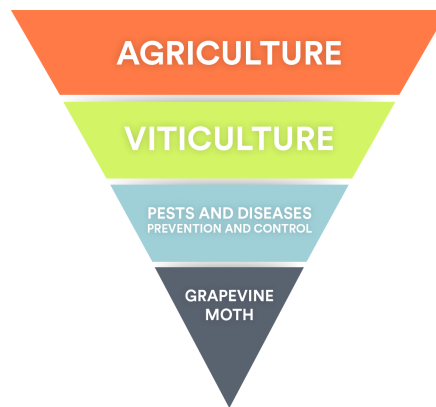
Figure 4.14: Evolution of the scope of the study

4.2.1 Personas and Scenarios

Following the methodology mentioned in 3.4.2 it is important to create scenarios and personas to get a better perception of how real people would reshape their activities and include a mobile application in their day-to-day.

4.2.1.1 Personas

As stated in 4.1.3.1 and 4.1.3.2 two distinct types of profiles of winegrower, the small and medium/large producer, and also some different stakeholders (lab and field technicians, cooperative and association members), were involved in the requirements gathering phase.

As the focus of this investigation is the farmer, two different personas were created:

- **Small winegrower** — is responsible for a small amount of hectares and performs the activity more as a hobby not as much because it is a source of income, but still is interested in making a profit. Usually is a fan of more traditional methods, also due to restrictions such as tractors not being able to reach these terrains. They're more interested in quantity versus quality, because the quality is not valued by their grape buyers. They are more instinctive when it comes to prevention and control, relying more on intuition in their decision-making process.

- **Medium/Large winegrower** — is generally a literate and technology proficient producer. Prioritizes more the quality of the grape and environmental questions than the small winegrower. Is interested in using technology to digitize daily operations that are done manually nowadays.

Another profile arises when analysing the goals (see 4.1.4) for an ICT solution to help prevent and control pests and diseases, the expert:

- **Expert** — some small and medium winegrowers are members of a cooperative/association that provides the means to achieve better wine production (quantity and quality), and in

order to do so their experts help in regards to pests and diseases prevention and control. This person or people provide advice and ensure that the winegrower is supported during crucial decision making moments.

4.2.1.2 Problem & Activity Scenarios

The personas and scenarios created for the brainstorming activity, before defining the scope of the study, can be found in Appendix G.

Having in mind those same personas it was possible to conceive different problem and activity scenarios now relating exclusively to Pests and Diseases Prevention and Control, more precisely to the Grapevine moth prevention. These aided in thinking of ways to achieve the goals and tackle the existing concerns mentioned above (see 4.1.4 and 4.1.4).

The problem and activity scenarios created for the small winegrower persona are listed in the table 4.1 and for the medium/large winegrower are listed in the table 4.2

Subject	Problem Scenario	Activity Scenario
Contact Expert	The farmer calls an expert and has to wait for his response and/or for him to be available to visit the field	The farmer sends a message, possibly attached with photos, allowing the expert to have a quicker response if a field visit is not necessary
Trap Placement and Count	In order to place moth traps in the terrain the farmer needs to get the trap from the expert, place it on the vineyard and weekly needs to collect the trap and travel to the expert for him to perform the adult count	The farmer can see instructions about trap placement and perform the count manually in the application or possibly automatically with the help of a computer vision software
Alerts	The farmer wants to read some instructions released on an agricultural notice but because the alert is not displayed in the Parish Council he can not read that information	By having all alerts archived in the application the farmer can easily search and check the information he was looking for

Table 4.1: Problem and Activity Scenarios for Small winegrower

4.2.2 Use Cases

Having in mind all the information mentioned above, from concerns, goals, and problem and activity scenarios it is possible to list important or frequent interactions between the user, that can be either one of these two actors: the winegrower or the expert, and the system. The following Fig. 4.15 provides a diagram of use cases.

Subject	Problem Scenario	Activity Scenario
Monitoring	In order to keep track of phenological development and to monitor the moth's impact on the vineyard the farmer takes photos on his phone but has difficulty to keep them organized in his camera roll	Using the application the user can organise photos by place taken and date, in order to better monitor his vineyard
Risk Assessment	To perform risk assessment the winegrower has to write all inputs (nests, eggs and perforations) either on paper or in an excel form. He also has to attach a tag to the sample in the vineyard in order to keep track of the counts that were performed there	By computerizing and centralizing these inputs in one application the user could easily and remotely access these informations and even view the moth's flight curve
Selective Prevention/Treatment	A farmer with a large terrain has more difficulty keeping track of the different plot's needs and evolution, he does so by having his workers filling reports on paper and then organizing that information in an excel	By allowing the user to map plots and pin trap's and sample's locations it would provide a more feasible way to perform selective prevention and treatment

Table 4.2: Problem and Activity Scenarios for Medium/Large winegrower

4.2.3 Hierarchical task analysis

This method of task analysis is explained in 3.4.2.3, and helps get a better view on the tasks needed in order to achieve a certain goal. For the two actors, here are the tasks they should be able to perform using the system:

- **Winegrower:**

  1. Map vineyard

  2. Receive alerts/warnings

  3. Get instructions about prevention and control

  4. Get treatments' information

  5. Access weather/sensor data

  6. Monitor Vineyard

  7. Perform risk assessment

- **Expert:**

  1. Access history of parcels

  2. Help with decision making/diagnosis

  3. Issue alerts/announcements

The graphical notation and decomposition of those tasks is shown in Fig. 4.16.
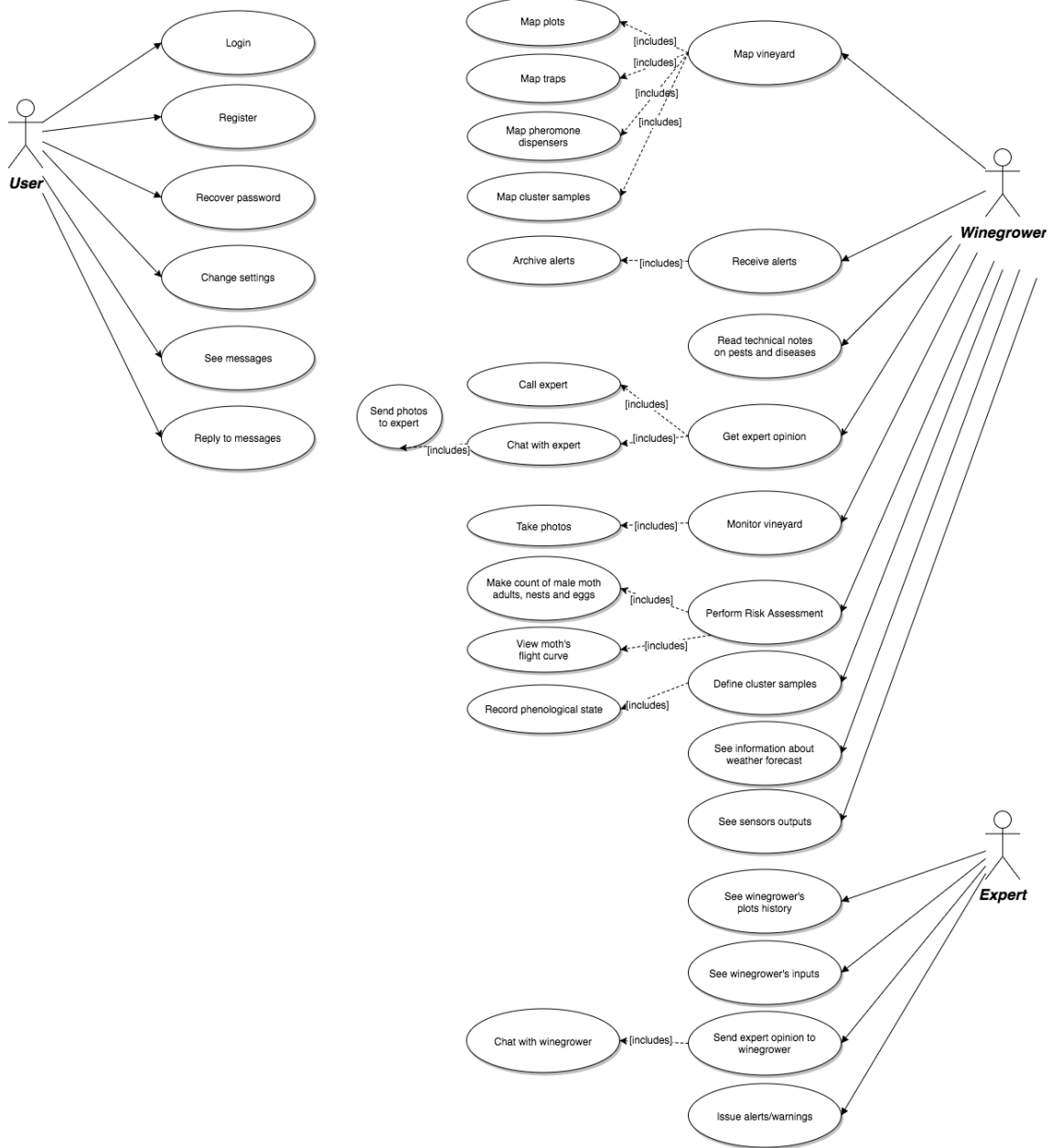
Figure 4.15: Use Cases Diagram
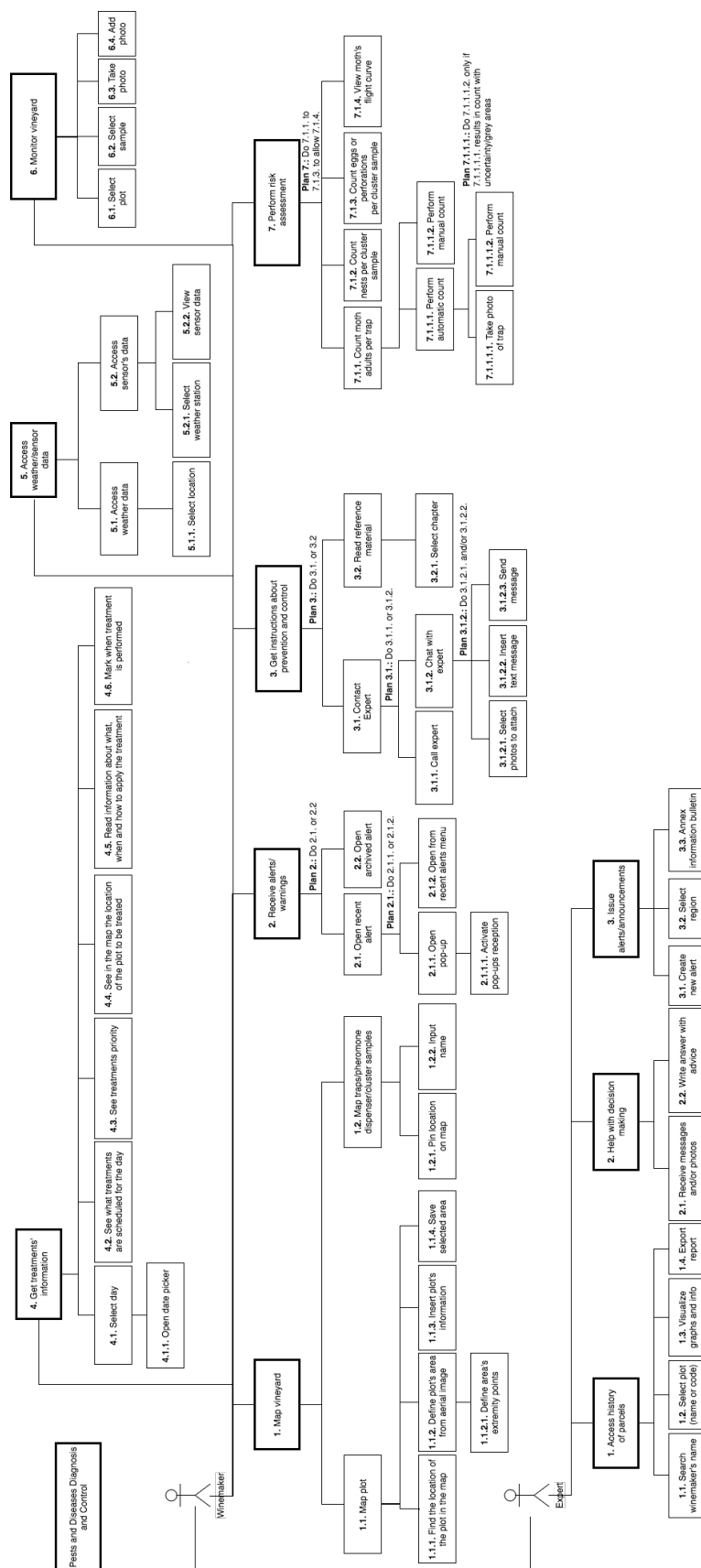
Figure 4.16: Hierarchical task analysis

4.2.4 Non-functional requirements

The representation models mentioned above refer to Functional requirements, a concept that is explained in 3.4.1. Listed bellow is a set of non-functional requirements that also impact the user experience:

- **Availability:** the application must be available at all times (both offline and online);

- **Documentation:** a quick-reference guide should be provided;

- **Efficiency:** the application must have the lowest possible response times whether we are talking about the Interface response time (must feel as native as possible) or the response times in the communication with the external services. Because of the context of use, performance should be adjusted to conserve battery power;

- **Extensibility:** should be possible to extend the system to support more pests and diseases relating to vineyards;

- **Interface:** the user interface must be very intuitive so that the user can access all the functionalities with minimal interaction with the software. The interface must also be responsive to all kinds of mobile devices' screen sizes. Screen luminosity should adjust to the environment.;

- **Maintenance:** the application should be built in such a way that it is easy to modify the implemented functionalities.

4.3 Phase Three - Design

Once the requirements have been established, the Design Phase begins. In this phase it was necessary to collect the rules, guidelines and design principles that would inform the creation of the concrete designs, that being, the prototypes. This selection was made accordingly to the target of users and the context of use. Even though the requirements in section 3.4.1 present two different actors, the winegrower and the expert, the design guidelines and prototypes developed relate only to the farmer. This decision was made due to the focus of this study being on farmers' interaction with a mobile application.

4.3.1 Material Design

In order to provide a "unified experience across platforms and device sizes" [10] Google [11] created an innovative design language based on classic design principles. Material's principles and guidelines served as the foundation for the design of this mobile solution, adding to these, guidelines from other authors.

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[10]https://material.io/guidelines/#introduction-goals
[11]https://www.google.com/intl/en/about/

Material lists three user interface design principles [12] to their philosophy:

- **"Material is the metaphor"** — by playing on the behaviour of paper and light, material allows the user to have a perception of objects and surfaces that is natural and intuitive. This metaphor provides an inherent understanding about the separation of things and relationship of things on the interface.

- **"Bold, graphic, intentional"** — means having bold typography and color choices, edge-to-edge imagery and intentional white space to create an immerse experience for the user.

- **"Motion provides meaning"** — motion provides increase of visibility and feedback.

When it comes to guidelines, Material provides an extensive documentation [13] for several aspects of the design, such as, style, layout, components, gestures and others. These guidelines depend directly on the solution's requirements, therefore the extracted concepts from Material are described in detail in section 4.4.

4.3.2 HCI4D Guidelines

The ICT4D Competence Center (ICT4DCC) at Fraunhofer AICOS, that aims to investigate, research and develop mobile solutions for areas such as: Agriculture, Health, and Citizens & Government collected a set of research based guidelines to tackle illiteracy or low literacy, either textual or technological, in developing countries [DMG⁺, Gie15].

Even though Portugal is considered a developed country, some of those principles are transversal and can be helpful to inform design decisions in this study. As mentioned in Appendix C, dating back to 2011 the Douro region had an illiteracy rate of 3.74%, with a deviation of 0.4% from the whole country. This can be an indication that for this target users, guidelines for semi-literate users can be more pertinent than those for illiterate users.

A list of relevant HCI guidelines for this research are presented next.

4.3.2.1 Ergonomic Factors

1. **"The avoidance of multi-function buttons is optimal for users with little experience"** — a button should only provide one functionality because multi-function buttons confuse users with little experience.

2. **"Over-cluttered buttons should be avoided"** — for examples alphanumeric keypads should be avoided because they provide issues regarding access and control.

3. **"Double-tapping is problematic to low-literate users and should be refrained"** — one click actions are more effective and have the highest recall.

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[12]https://material.io/guidelines#introduction-principles
[13]https://material.io/

4.3.2.2 Interface Design

- **Text**

    1. **"Illiterates and semi-literates have different requirements"** — the advice for fully illiterate users is to use minimal text but it should be kept in mind that this could be prejudicial for semi-literal users. For semi-literal users text has been show to reinforce semi-literates reading skills.

    2. **"Augment text with other modalities"** — using audio and images can provide illiterate users a replacement for text and increase ease of interaction for semi-literate users.

- **Graphics**

    1. **"Use hand-drawn graphics instead simplified abstract or photorealistic representations"** — hand-drawn cartoons are preferred and more easily understood by illiterate or semi-literate users.

    2. **"Do not use icons on their own"** — using textual descriptions next to icons allows for an easier understanding of the functionality provided.

    3. **"Use icons and graphics understood by the target culture"** — icons should reflect the culture and experiences of the target-users.

    4. **"Indicate that icons can be selected"** — icons' behaviour should change when selected to convey that they're selectable.

4.3.2.3 Navigation and Information Architecture

1. **"Avoid hierarchical structures"** — for low literacy users linear navigation structures should be favoured over hierarchical structures because they're easier to understand.

2. **"Encourage exploration of the interface"** — by providing feedback, undo functionalities and confirmation dialogues after high risk operations, the user feels less nervous to explore.

3. **"Keep the home screen simple"** — in order to avoid intimidating novice users the home screen should be kept simple.

4. **"Minimize the number of tasks possible on each screen and offer only one way to accomplish them"** — offering more than one way to perform a task might confuse some users.

5. **"Avoid scrollbars"** — some users do not realize that functionalities appear by vertical scrolling.

4.3.3 Designing for Older People

As mentioned in section 4.1.2 most farmers in Portugal belong to an older age group, making it important to look into guidelines for designing for older people. The following guidelines are a selection of relevant recommendations:

1. **Colour** — elderly people are less sensitive to colour contrast, therefore it is harder for them to distinguish some colours [Phi11].

2. **Buttons** — bigger buttons with larger touch areas may give better performances but the size of the button should be considered based on how it'll affect other elements, such as, the screen layout [Phi11]. For example, the designer may need to split working displays or make use of scroll bars.

3. **Text size** — when it comes to font sizes, 14-point size or higher is recommended and so is the use of black text on white background.

4.3.4 Context of Use

It is also important to take the context of use of the application into consideration. Most of the application's functionalities need to be performed in the field, therefore outdoor use has some problems associated. In order to use a device under direct sun light contrast is very important [OT11]. Placing controls in a consistent location might make it easier to overcome the problem of fingertips on the screen combined with sun glare [14]. If possible, placing the most frequent interactions on the same side of the screen, at a reachable distance, allows the user to perform one-handed interactions. Those reachable areas are illustrated in Fig. 4.17.
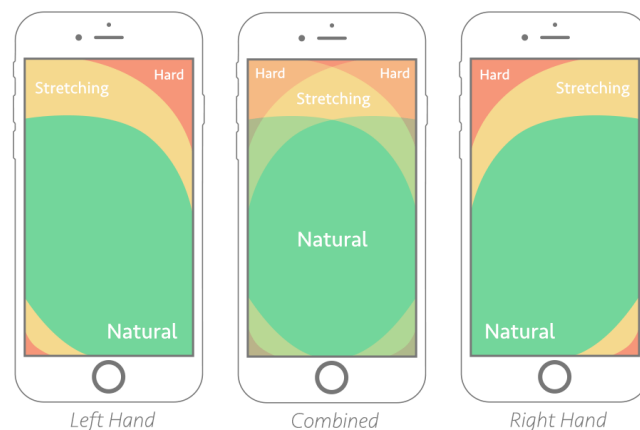
Figure 4.17: Thumb Zone Mapping [15]

4.3.5 Conflicts

Conflicts will naturally arise when taking all these guidelines into consideration, here is a list of some of them:

- **Gestures** — Material relies heavily on touch mechanisms and activities that can provide a richer user experience. A problem arises, as mentioned in item 3, even double tapping can be hard for low literate users. To tackle this issue Material provides a series of instructions on gesture education [16].

- **Navigation** — Conflicting with the guideline in item 1, Material's navigation organizes content hierarchically. Also to overcome the guideline described in item 5 Material suggests to show content overflow in the view's initial scroll position by cutting of content above the fold, encouraging further exploration, as illustrated in Fig. 4.18.
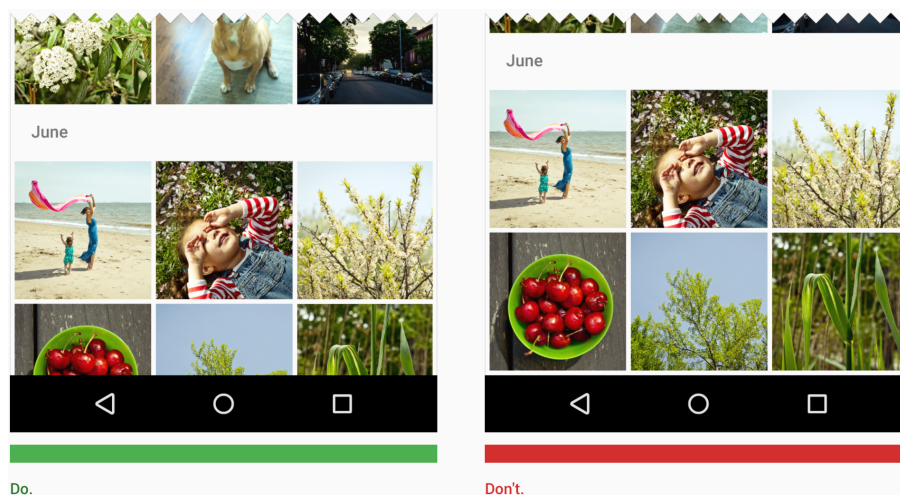
Figure 4.18: Scrolling Guideline [17]

- **Icons** — Material provides over 900 icons to be used in web, Android and iOS development [18]. They can be defined as somewhat abstract graphics, going against the guideline in item 1. On the other hand these icons have been widely adopted, providing consistency between different applications. Also, in some components, under certain conditions, Material indicates that icons should not be accompanied by text labels, conflicting with the guideline presented in item 2. Finally, Material's icons are not culturally sensitive, opposing item 3.

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[16] https://material.io/guidelines/growth-communications/gesture-education.html
[17] https://material.io/guidelines/components/grid-lists.html#grid-lists-behavior
[18] https://material.io/icons/

4.4 Phase Four - Prototyping and Evaluation

After looking into some design guidance from different authors, in section 4.3, it is time to develop concrete designs and evaluate them.

4.4.1 Application's Navigation

In order to design the navigation for the mobile application, common user tasks based on the system's requirements (mentioned in section 4.2) were first prioritized, as illustrated in 4.19.

View risk level	Perform Risk Assessment	Map vineyard
View newest alerts	View heat map	View archived alerts
View moth's flight curve	Read treatment's information	Edit preferences
View treatments' calendar	Monitor vineyard	Edit plot's info
Read treatment's information	Add plot	Edit sample's info
View Map	Add trap	Edit trap's info
Contact expert	Add sample	Edit treatment's info
View weather/sensors data	Add treatment	Edit pheromone dispenser's info
Read reference material	Add pheromone dispenser	
high	medium	low

Figure 4.19: Prioritisation of common user tasks

The different priority levels helped to inform the application's navigation, giving prominence in the UI to the tasks with highest priority.

4.4.2 Low Fidelity Prototype

Low fidelity prototypes, as stated in 3.4.4.1 provide a quick and easy way to create alternative design versions. Firstly, sketches on paper (see Fig. 4.20) allowed to experiment with different layouts and to test possible application flows, taking into account requirements and tasks priorities.
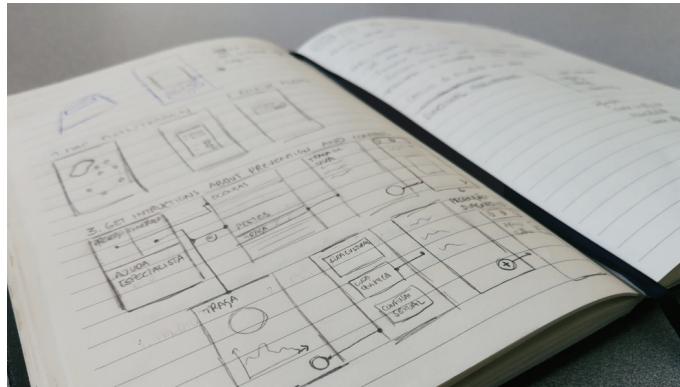
Figure 4.20: Paper Sketches

After some iteration the final low fidelity prototype was created using the Balsamiq Mockups [19] wireframing tool. The prototype's screens are provided along with the application flow in Figures 4.21, 4.22, 4.23, 4.24 and 4.25.
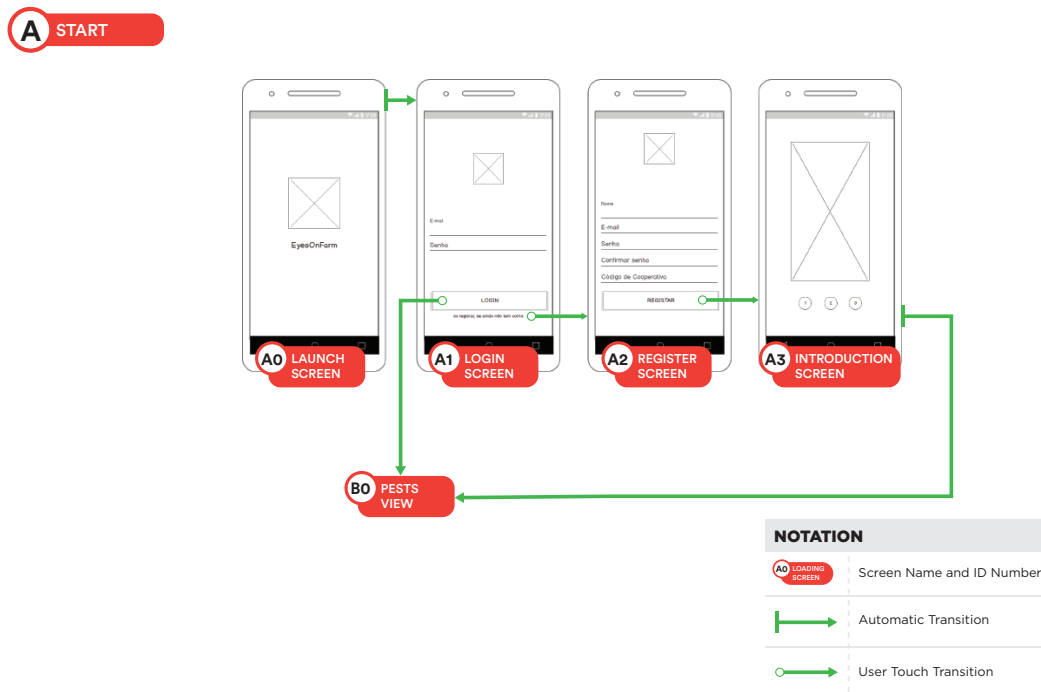
Figure 4.21: App Flow - Start
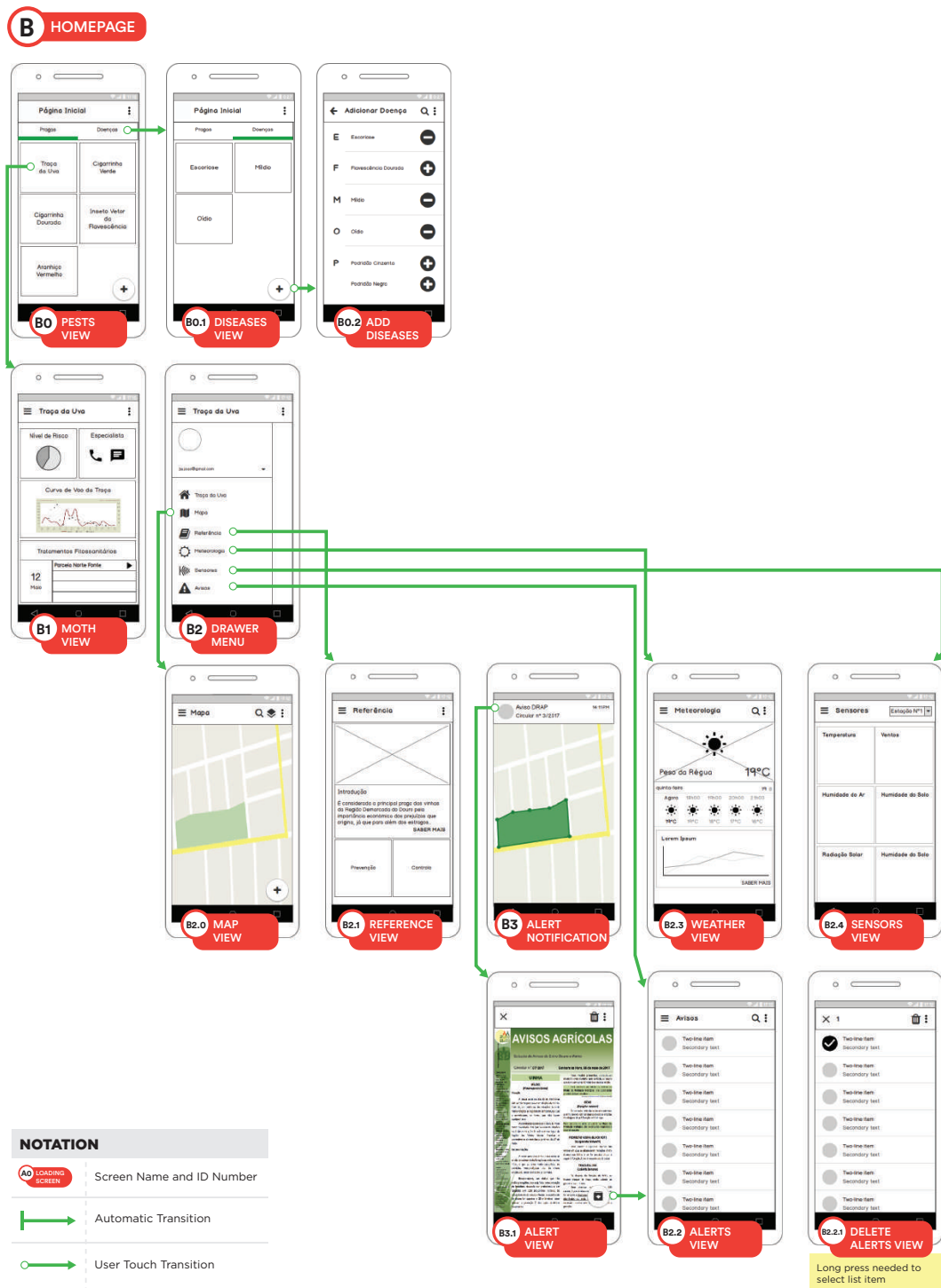
Figure 4.22: App Flow - Homepage
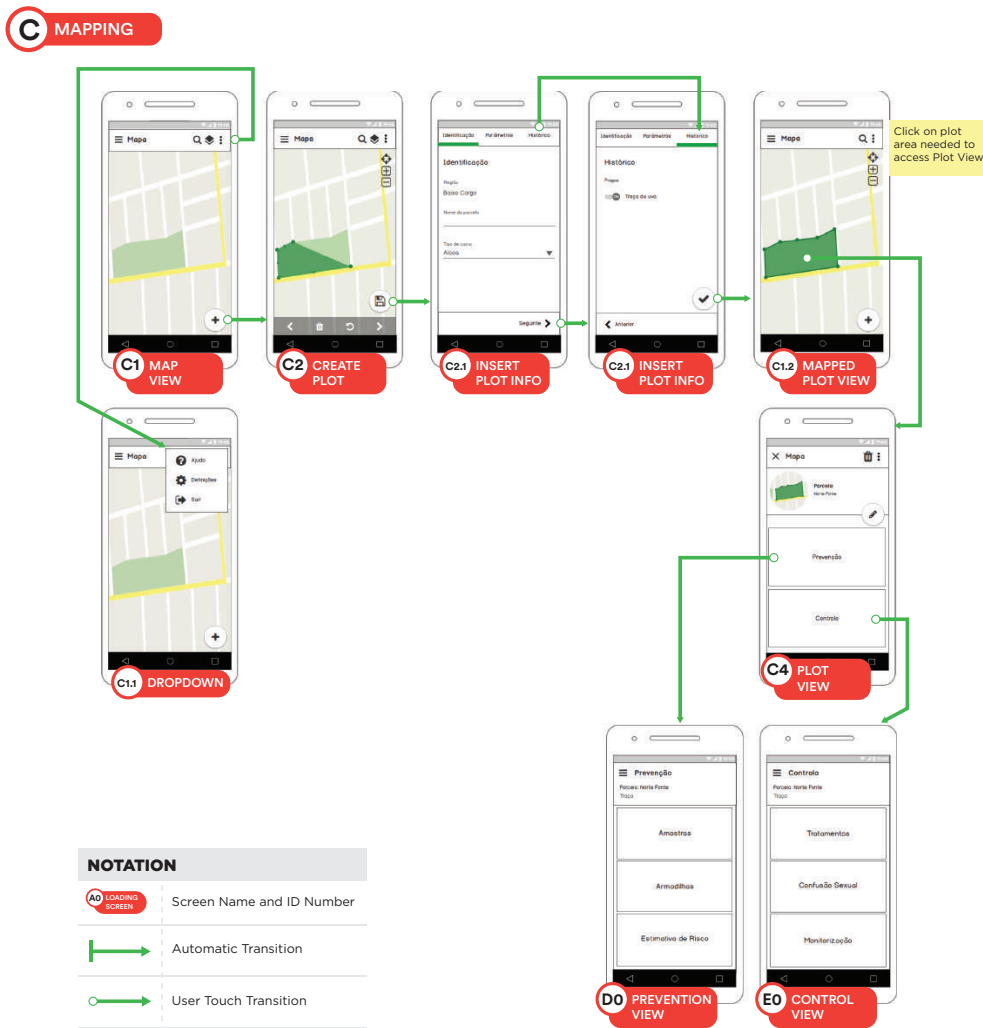
Figure 4.23: App Flow - Mapping
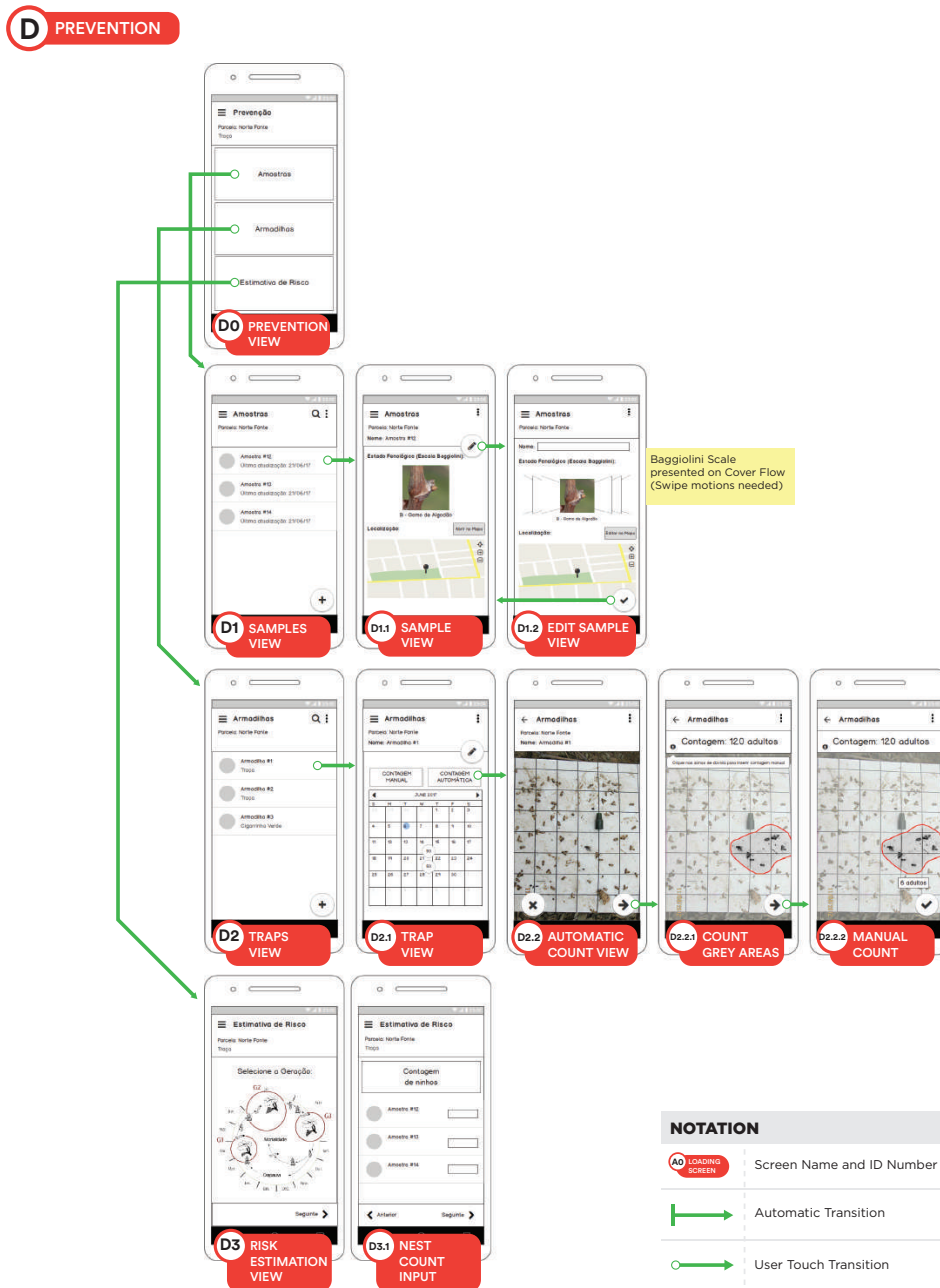
Figure 4.24: App Flow - Prevention
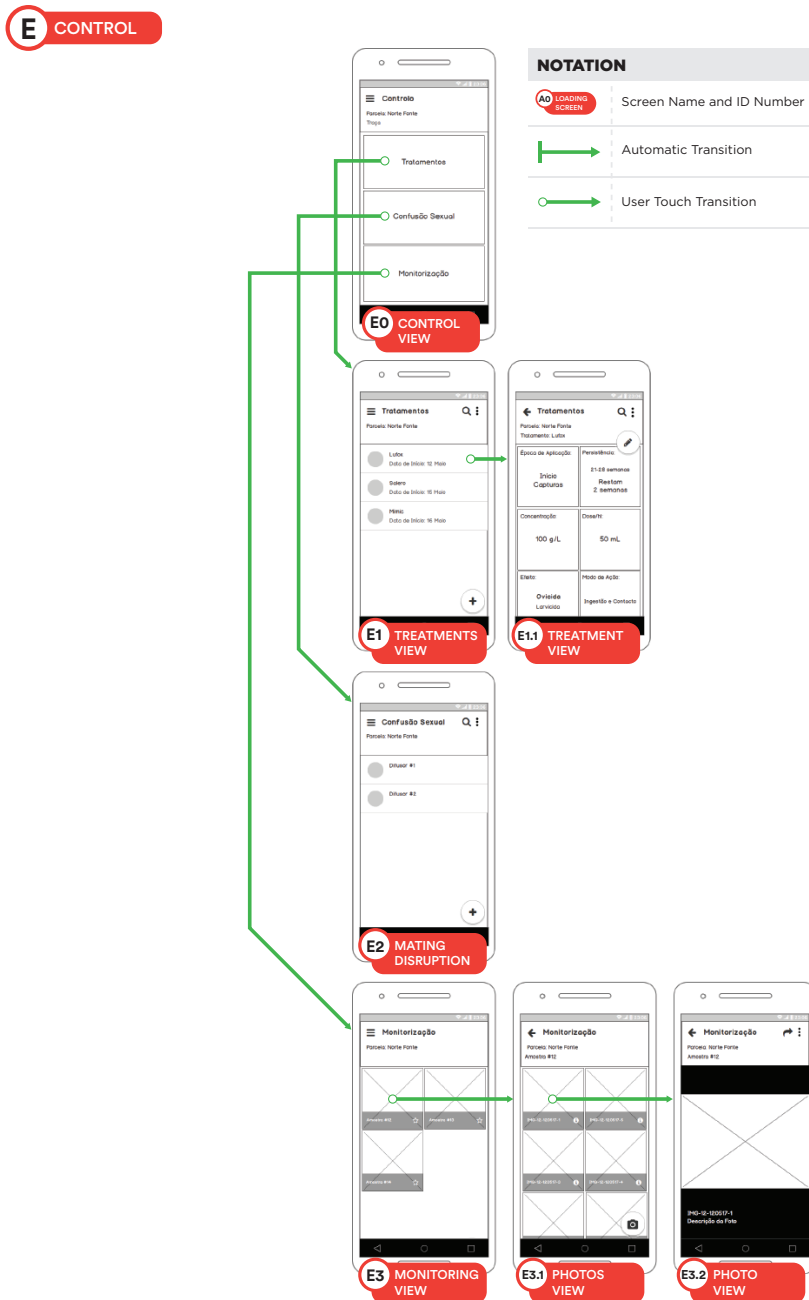
Figure 4.25: App Flow - Control

4.4.2.1 Components

The following Material components [20] were used in the creation of this prototype:

- **Toolbar** — the app bar was used, allowing the user to open the drawer or navigate through the apps' hierarchy, and to perform actions such as, search or secondary ones, such as get

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[20] https://material.io/components/

help and log off (e.g. Screen C1.1. in Fig. 4.21).

- **Navigation** — The app navigation was created based on the prioritization of the most common tasks 4.4.1. Some of the highest prioritized tasks were included in the navigation drawer to allow access to top-level, unrelated views (e.g. Screen B2 in 4.22). Tabs were used to allow an easy switch between sibling views (e.g. Screen B0 in Fig. 4.22).

- **Buttons** — Floating Action Button (FAB), flat and raised buttons were used. FABs were used when the action needed to be readily available (e.g. Adding a plot - Screen B2.0. in Fig. 4.22). Flat buttons were used when distraction from content needed to be minimized (e.g. Screen B2.1. in Fig. 4.22) and raised buttons when functions needed to be emphasized (e.g. Screen D2.1. in Fig. 4.22).

- **Cards** — were used to display content composed of different elements, that was not directly related and were presented in card collections (e.g. Screen B1 in Fig. 4.22). Special care was taken to not overwhelm the interface with too many cards or cards with too much graphic content in order to follow the guidelines in items 3 and 4.

- **Lists** — for information that needed to be scanned or compared lists (e.g. Screen E2 in 4.25) or grid lists (e.g. Screen E3.1 in Fig. 4.25) were used.

- **Steppers** — were used to avoid scrolling, following the guideline in item 5 (e.g. Screen C2.1. in Fig. 4.23).

Even within the same component Material provides different approaches and guidelines depending on tasks and pretended usage and behaviour. For example, the FAB can have behaviour of flinging out related options and that would provide a way for the user to add directly to the map not only a plot, but a trap, pheromone dispenser or sample. This was not the design decision because of the guideline listed in item 1.

Unfortunately due to time and bureaucratic constraints it was not possible to evaluate the low fidelity prototype. Methods such as card-sorting [21], performed with farmers, or cognitive walkthrough (see 3.4.4.2), performed with experts would have been very helpful to inform the design of the high fidelity prototype.

4.4.3 High Fidelity Prototype

In order to better provide a more realistic interaction, an hi-fi prototype was developed. This prototype only included the necessary views to perform usability testing with real farmers. Therefore a selection of tasks to be tested had to be made beforehand and are included in the Appendix I.

For the design of an hi-fi prototype different design aspects need to be taken into consideration.

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[21]https://www.usability.gov/how-to-and-tools/methods/card-sorting.html

4.4.3.1   Colour

Colour contrast is something guidelines for both older people (1) and for outdoor usage (4.3.4) mentioned, therefore colours were selected using Material's Color Tool [22]. This tool allowed to generate a color scheme and provided information about the colours accessibility (their legibility to be the colour background for white or black fonts and minimum opacity required).

Table 4.3 lists the selected colours for the interface design:

Colour	Accessibility
Primary Colour: #63d768	
Primary Light Colour: #98ff98	
Primary Dark Colour: #27a53a	
Secondary Colour: #FF7A46	

Table 4.3: Colour Scheme

4.4.3.2   Icons

Material provides a catalogue [23] of over 900 icons, with each one attached to it is symbolization (e.g. a cross is associated with the add action). Some icons for this prototype's design were extracted from the catalogue with a different symbolism from the one provided by Material. Those exceptions are listed in table 4.4.

Other icons used to transmit an action, status or for decoration purposes are listed in table 4.5. The weather and sensor related icons were obtained from a different icons library [24].

4.4.3.3   Design Changes

Even though the low fidelity prototypes were not evaluated by users or experts, after re-evaluating the low-fi prototype some design changes were made. These are listed in table 4.6. The hi-fi prototype was created using the vector design tool Sketch [25] and all the interfaces created are provided in Appendix H.

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[22]https://material.io/color/
[23]https://material.io/icons/
[24]https://erikflowers.github.io/weather-icons/
[25]https://www.sketchapp.com/

Icon	Material's Symbolism	Intended meaning
	App	Grid view
	Warning	Risk Level
	Move to inbox	Alerts received
	Remove red eye	Seen/Unseen

Table 4.4: Icons intended meaning

Icon	Intended meaning
	Treatments
	Sensors
	Mapped sample
	Mapped trap
	Mapped pheromone dispenser

Table 4.5: Other icons

Screens	Changes

Navigation — The navigation drawer was replaced by bottom navigation in order to provide quicker access to high priority tasks. This also meant that those functionalities would be available without the need to click on the hamburger icon, which raised concerns about being a recognizable action without a label attached. The expert functionality went from the Moth View (Screen B1 in Fig. 4.22) to also be included in the bottom navigation, allowing quick navigation between top-level views. Also, instead of having archived Alerts in the drawer or in the bottom navigation they can be accessed in the Moth View with a card displaying the latest alerts and a status of already read or not.
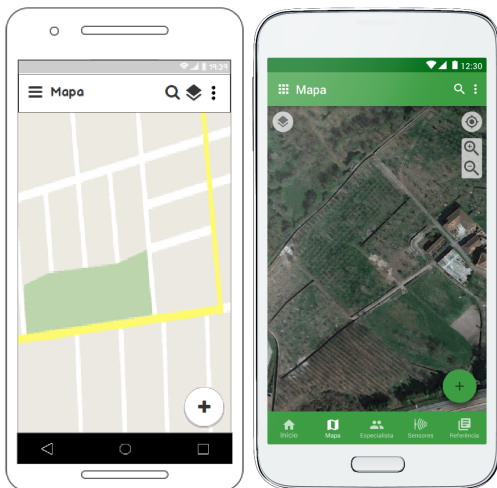
Map View — The icon that opens a menu to change the map view (satellite, terrain or heatmap) was changed from the app bar to the top-left of the map viewing area. This was done because of the concern that the iconography was not clear enough for users to understand it would allow to perform actions related with the map.
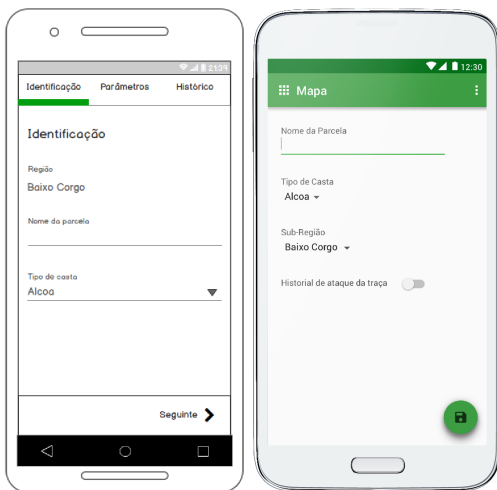
Insert Plot Info — In this interface the stepper were discarded because of the lack of information input needed.
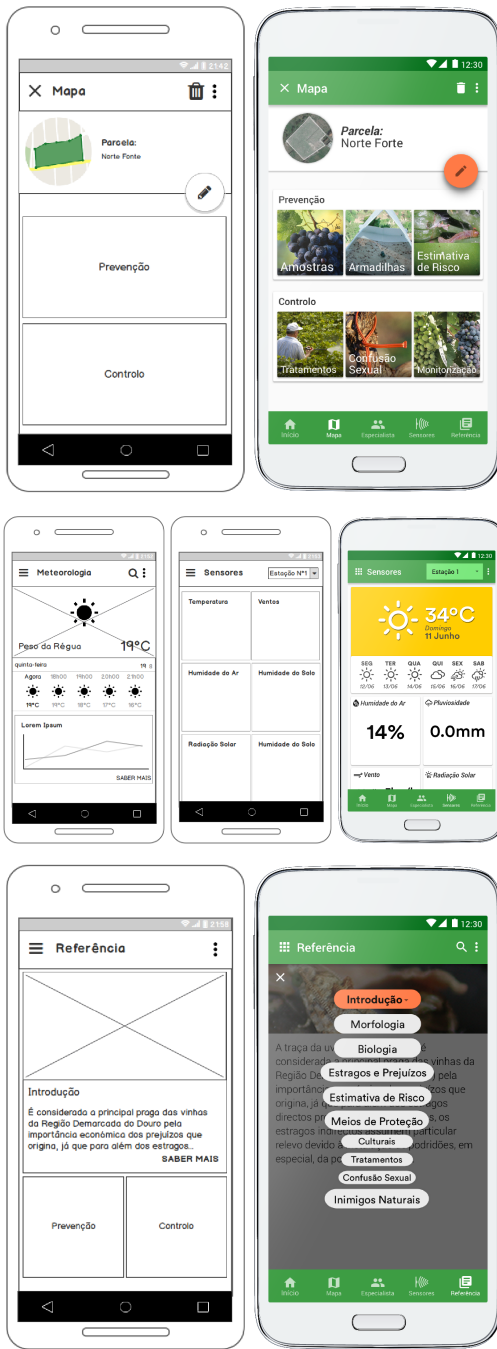
Plot View — This view was redesigned to have cards nested inside cards, even though it went against Material's guidelines. This allowed the user to perform the same actions with fewer clicks.

Merge of views — The weather and sensors views were merged because of how related they were to one another, providing the user both data in a single view.

Reference View — Previously organized with a collection of cards the reference view was altered to provide navigation between the content in the form of chapters.

Table 4.6: Design Changes

4.4.4 Evaluation

After creating the hi-fi prototype, it was time to evaluate it using real farmers and to do so a usability test was conducted with winegrowers from the DDR (the usability test protocol can be seen in detail in Appendix I). The prototyping tool Invision [26] and the Craft plugin [27] were used to

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[26] https://www.invisionapp.com/

[27] https://www.invisionapp.com/craft

add animations, gestures, and transitions to the static interfaces created using Sketch, as illustrated in Fig. 4.26.
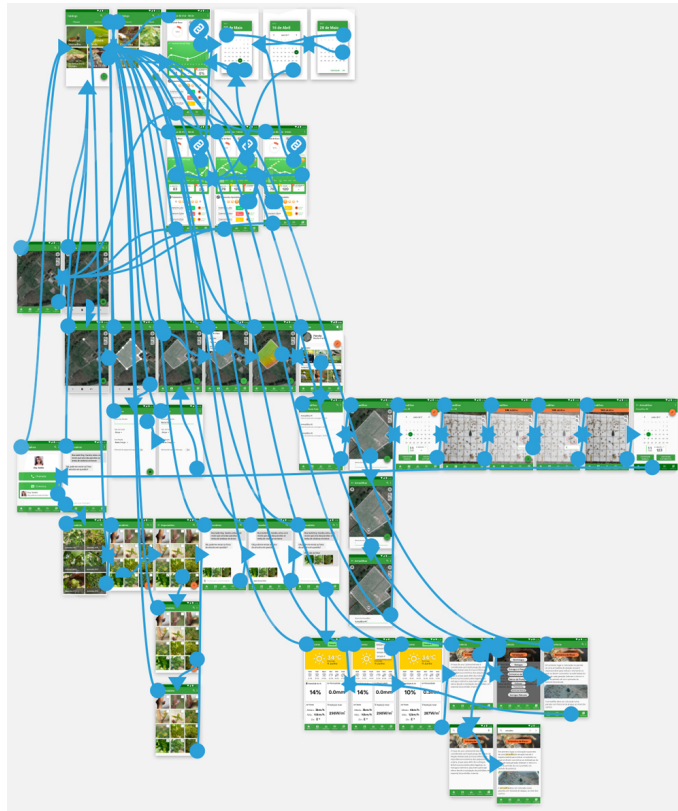
Figure 4.26: Craft in Sketch

4.4.4.1 Participants

The number of required participants for the test was established as at least 5 and up to 10 people, as recommended by Nielsen's and Landauer's analysis of return on investment when performing a usability study [NL93]. The recruitment process was performed by a local cooperative in *Peso da Régua*. In order to get a good sampling, the selection criteria for the recruitment was based on three factors, the type of producer, the participant's technological proficiency and educational level. It was important to perform tests with small and also medium/large winegrowers, with people that had never used a smartphone and others that owned one, and with very different levels of education.

4.4.4.2 Context of Use

The test was conducted in a room in the cooperative facilities, a place familiar to all participants, which would allow them to be more comfortable. It is important to note that using the application in a room sitting down it is very different from the expected context of use. To even out this

difference the test was conducted next to a big source of light, in order to simulate the expected glare the users would get using the device outdoors.

4.4.4.3 Test procedure

At first the participants were informed about the context of the study, similarly to the introduction given when performing the interviews (see Appendix D). Next it was emphasized that the test did not serve to evaluated the user, but the system. This was important because most of the users did not know what a usability test was.

The test had a time limit of 1 hour and was conducted with only one person with the role of guiding the participant, before (trainer) and during the session (facilitator). In order to facilitate the recording of the participant's actions and comments a tripod and camera were used to record the test with the consent of the participant.

Participants were instructed to use the think-out-loud method during the test. After, if there was any free time remaining, an open conversation with the participant allowed to not only talk about aspects relating to the prototype's usability but to possible improvements when it came to features.

4.4.4.4 Tasks

As previously mentioned the hi-fi prototype was developed with the tasks that would later be evaluated in mind. The selection of those tasks was done based on two factors: the most important things every user would be able to accomplish using the app and also different types of interaction. For example, tasks such as creating and mapping a sample, trap or pheromone dispenser followed the same premise, therefore there was no need to evaluate all three of them.

The tasks the users were asked to perform and the ideal flow for their successful completion is listed in table 4.7.

Task	Ideal Flow
Task 1.1 — Change the data range of the moth's flight curve to the 16th of April - 11th of June	[Click 28th May button > Edit date in picker to 16th of May]
Task 1.2 — See the number of captured adults and nests counted during the week of 23-29 April	[Click on 23rd-29th of April]
Task 2 — Open the latest alert sent out by DRAP	[Click on button with label "Circular no 13" on "Avisos Agricolas" Card]
Task 3 — See the scheduled treatments for the 10th and 11th of June and see which one has more urgency	[Scroll to bottom of "Pagina Inicial" screen > Swipe left over dates on "Tratamentos" Card or Click on right arrow]

Task 4.1 —- Create and map a new plot	[Click on "Mapa" in the bottom navigation > Click on plus FAB > Simulate click on screen to map points > Click on check FAB > Simulate field inputs > Click next > Simulate field inputs > Click on save floating action button]
Task 4.2 —- Change the view to a heat map in order to see what areas of the plot are more prone to being attacked by the grapevine moth	[Click on layers icon > Select on menu "Mapa de Temperatura"]
Task 4.3.1. —- On that same plot, add and map a trap	[Click on plot > Click on "Armadilhas" in "Prevencao" card > Click plus FAB > Simulate click on map to pin trap location > Simulate input of trap's name > Click check FAB]
Task 4.3.2. —- Now perform an automatic count of adult moths in that trap	[Select day in date picker > Click Automatic Count > Simulate photo capture of trap > Click next > Input grey area manual count > Click Save]
Task 5 —- Contact expert "Eng. Sandra" by chat and send her three images from sample called "Amostra #12" with a question attached	[Click on "Mapa" in the bottom navigation > Click on plus FAB > Simulate click on screen to map points > Click on check FAB > Simulate field inputs > Click next > Simulate field inputs > Click on save floating action button]
Task 6 - Read air humidity from the sensor in the weather station "Estacao 2"	[Click on "Sensores" in the bottom navigation > Select weather station "Estacao 2"]
Task 7 - Open reference information about how to apply traps	[Click on "Referencia" in the bottom navigation > Search "armadilha" and go through search results OR Click on dropdown and go to "Estimativa de Risco"]

Table 4.7: Usability Test Tasks

4.4.4.5 Metrics

To measure the effectiveness of the system the following metrics were recorded:

- **Task completion rate** — the task is considered completed when the task goal is achieved.

- **Errors** — are considered errors actions that do not contribute to task completion.

- **Assistance** — when the participants cannot proceed on a task, the test facilitator can give help. Two types of assists can be given, a less direct assistance (light assist), and a more

direct and intrusive assistance (heavy assist), for example the facilitator clicking on the screen for the participant, used only as a last resort.

To evaluate the system's efficiency the time on task (TOT) was recorded. Because the think-out-loud method was used, for better comparison, the TOT measures only to the time the user interacted with the prototype, not the time when they conversed with the facilitator. Also satisfaction was measured through the System Usability Scale (SUS) questionnaire administered after the test.

4.5 Summary

The user centred design methodology was used encompassing the following phases:

- **Phase 1: Requirements Gathering** — During this phase an analysis of the existing android applications in the market were analysed, the research sample was established as wine-growers in the Douro region and research methods were used to collect data to inform the system's requirements. Interviews and field visits were the chosen methods.

- **Phase 2: Analysis** — After collecting data it was necessary to analyse it, therefore personas and problem and activity scenarios were created. Also use cases and hierarchical task analysis diagrams were made. The scope of the study evolved from Agriculture in general to Prevention and Control of the grapevine moth.

- **Phase 3: Design** — With the requirements for the system established it was necessary to study design guidelines focused on the target audience and context of use. These would later inform the creation of the concrete designs.

- **Phase 4: Prototyping and Evaluation** — Low and high-fidelity prototypes were designed and evaluated with real winegrowers by performing a usability test.

The results from the usability test are presented and discussed in the next chapter 5.

Methodology

Chapter 5

Results and Discussion

5.1 Participants

User #	Gender	Age	ISCED	Mobile Phone	Type of producer
U01	M	77	1	Has never owned one	Small
U02	F	64	3	Basic Phone	Small
U03	M	59	3	Smartphone	Medium/Large
U04	M	53	2	Smartphone	Small
U05	M	43	3	Smartphone	Medium/Large
U06	M	46	3	Smartphone	Medium/Large

Table 5.1: Participants

As described in table 5.1 six participants were apart of this test, with an average age (rounded to nearest year) of 57 years old. Four out of six participants owned a smartphone, one running Apple's operating system iOS and the rest android. Relatively to the other two participants, one had never owned a mobile phone, only using a fixed landline and the other participant used a basic phone, without a touch screen. Regarding the type of producer, three participants were small winegrowers and three medium/large winegrowers. Based on the International Standard Classification of Education (ISCED), one participant only finished primary education, one lower secondary education and four upper secondary education. Photos of participants performing the test can be seen in Fig. 5.1.
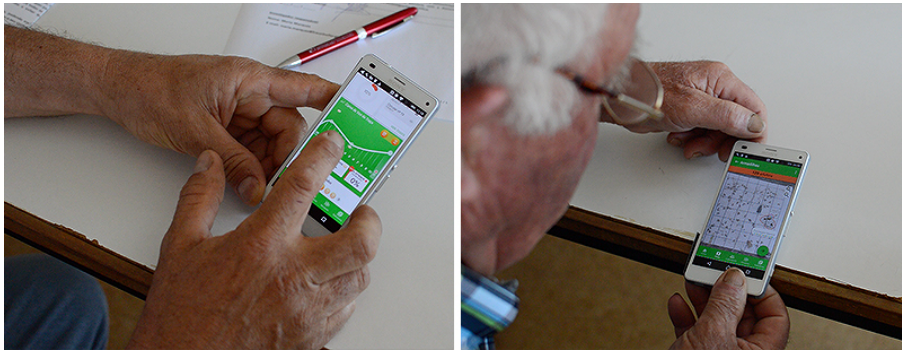
Figure 5.1: Participants during the test

5.2 Performance results

A full report on the metrics relating to efficiency and efficacy of the system can be read in Appendix J. A summary of the results is shown in table 5.2, which includes data relating to time on task, effectiveness of tasks, errors and assists. In Fig. 5.2 we can see task completion rate of each user, where it is possible to visualize that the first two users (U01 and U02), that were not smartphone users, were the ones who needed more assistance. In Fig. 5.3 data regarding the number of errors and assists by each user is provided. U01 had the most number of errors and assistances, probably due to his age and never having owned a mobile phone. Other relevant graphs that were created are: the one relating to user metrics by task, in Fig. 5.4. It is possible to conclude that the tasks that generated more issues were T3, T4.3.1 and T7 and the ones that were executed by most users were T1.2, T2, T4.3.2, and T6. Also the graph relating to the total analysis of the metrics by task, can be seen in Fig. 5.5.

USER #	TOTAL TIME ON TASK [SECONDS]	TOTAL UNASSISTED TASK EFFECTIVENESS [(%)COMPLETE]	TOTAL LIGHTLY ASSISTED TASK EFFECTIVENESS [(%)COMPLETE]	TOTAL HEAVILY ASSISTED TASK EFFECTIVENESS [(%)COMPLETE]	TOTAL ERRORS	TOTAL ASSISTS (LIGHT)	TOTAL ASSISTS (HEAVY)
U01	1142	0%	46%	100%	26	26	7
U02	674	28%	55%	100%	11	12	6
U03	141	91%	100%	100%	2	1	0
U04	303	82%	91%	100%	2	2	1
U05	466	64%	82%	100%	11	5	2
U06	469	64%	73%	100%	0	6	3
Mean	532,5	55%	80%	100%	8,67	8,67	3,17
Standard Deviation	349	40%	30%	0%	9,8	9,4	2,8
Min	141	0%	46%	100%	0	1	0
Max	1142	91%	100%	100%	26	26	7

Table 5.2: Summary of results
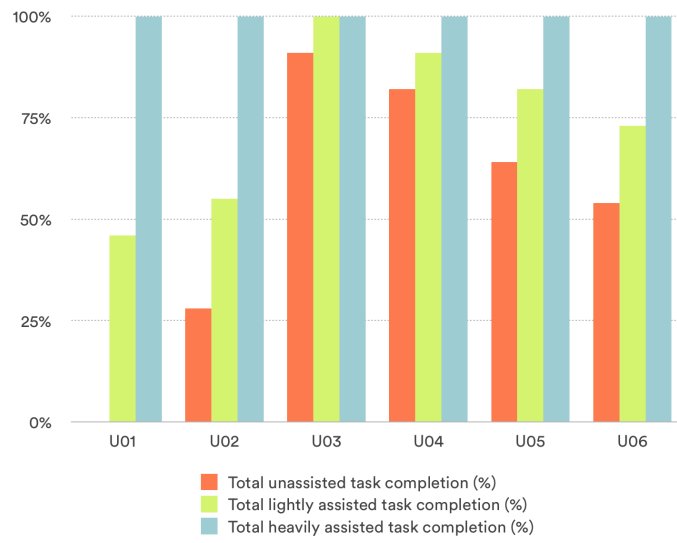
Figure 5.2: Task completion rates
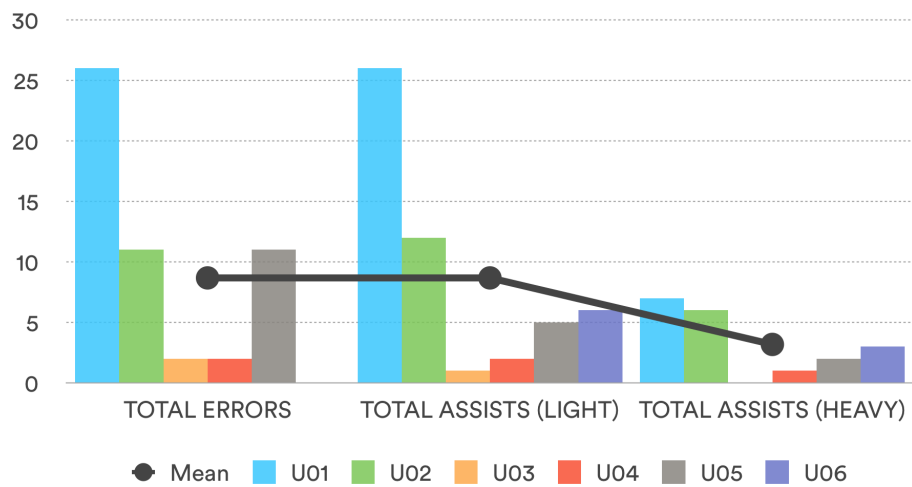
Figure 5.3: Total errors and assists

69
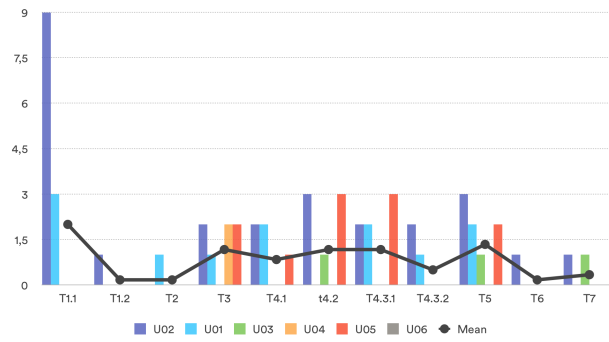
(a) User errors by task
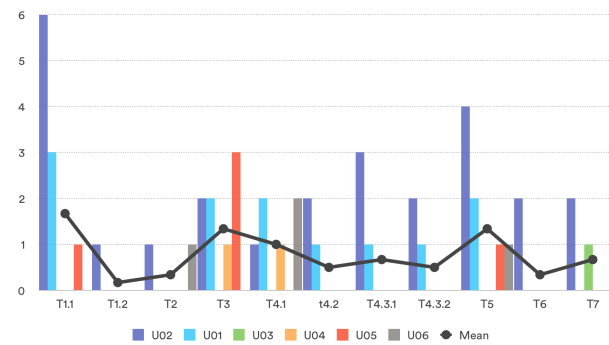
(b) User light assists by task
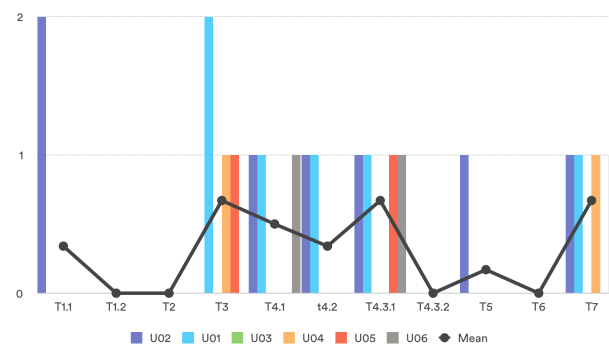
(c) User heavy assists by task
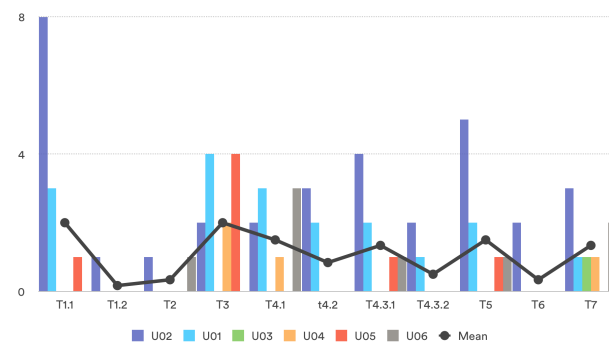
(d) User total assists by task

Figure 5.4: User metrics by task

(a) Total errors by task

(b) Total light assists by task

(c) Total heavy assists by task

(d) Total both assists by task
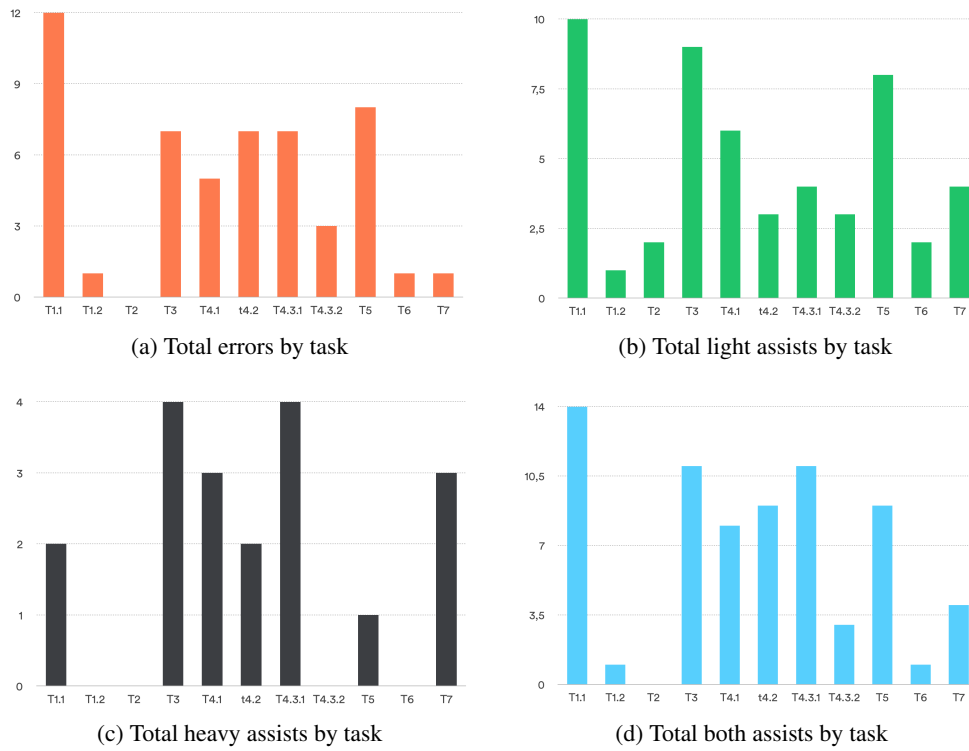
Figure 5.5: Total metrics by task

5.3 Satisfaction results

The results of the SUS can be seen in table 5.3 and Fig. 5.6. The mean of the SUS Global Score was 75.9 (SD = 5.8). The lowest score registered was 65 and the highest was 82.5.

	SUS Score	SUS Learnability	SUS Usability
U1	65	2,5	62,5
U2	77,5	5	72,5
U3	77,5	12,5	65
U4	82,5	20	62,5
U5	80	10	70
U6	72,5	17,5	55
Mean	75,9	11,3	64,6
Standard Deviation	5,8	6,3	5,7
Min	65	2,5	55
Max	82,5	20	72,5

Table 5.3: SUS Scores and Sub-scores
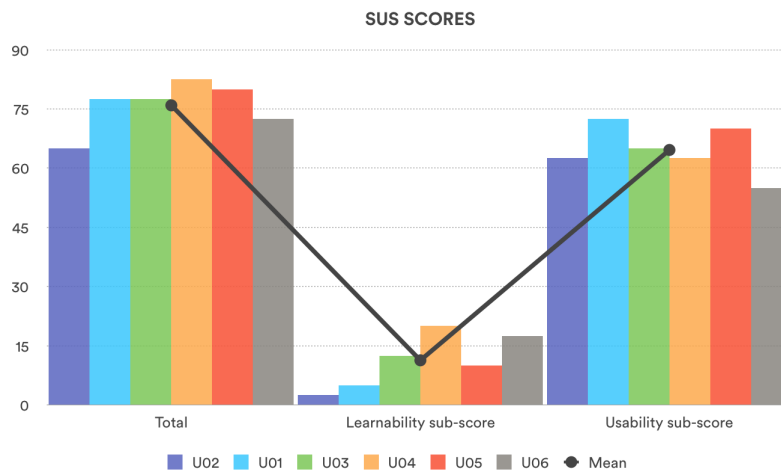
Figure 5.6: SUS Scores and Sub-scores

5.4 Observations

Besides the quantitative data it was necessary to collect qualitative data. The following table 5.4 includes commentaries on each user's issues, suggestions, and observations. This helped to see that some issues were recurring while others not that much. The recurring ones are tagged with an asterisk.

User #	Observations
U1	• Difficulty reading smaller text • Scrolling was not perceptible ***** • Performed hard long presses when clicking on interface • Thought the android navigation bar [a] belonged to the prototype's interface • Difficulty understanding arrows and their action e.g. when changing date in material's date picker also clicked the arrows to change the day • Hard time clicking on buttons without a delineated or a small touch area ***** • Thought titles and text were clickable ***** • Had an easy time clicking cards with images • Most times, when the action needed to be performed using a FAB, the participant clicked on one of the icons on the navigation bar • Material's icons such as the "layers", "send" and "add" were not understood

[a]https://developer.android.com/training/system-ui/navigation.html

	• Scrolling was not perceptible *
	• Hard time clicking on buttons without a delineated or a small touch area *
	• Thought the creation of parcel would be done by pressing points on the map directly, without having to press the plus FAB first. *
	• Confusing with plus symbolism when creating and mapping a plot, suggested using a pencil icon
U2	• Thought the "my location" icon meant rotate
	• Understood the zoom icons' actions
	• The "layers" icon looked like an arrow to the participant *
	• Did not understand that the plot was clickable *
	• Though the titles were clickable (e.g. clicked Armadilha on traps view to create a new trap) *
	• Clicked on the whole photo when checking the photos to send on chat *
U3	• Did not understand the swipe motion was provided on Homepage when selecting treatment day
	• Layer icon was not immediately recognized *
U4	• Scrolling was not perceptible *
	• Thought the creation of parcel would be done by pressing points on the map directly, without having to press the plus FAB first. *
	• Confusion about map temperature concept
	• Had a hard time understanding where he could find information about trap's placement

	• Tried to perform horizontal scroll on graph
	• Scrolling was not perceptible *
	• Took a little bit of time to associate colour's to priorities in treatment's calendar
U5	• Thought the creation of parcel would be done by pressing points on the map directly, without having to press the plus FAB first. *
	• Clicked on photo area instead of checkboxes when selecting photos *
	• Suggested that sensors would be very helpful for mildew prevention and control
	• On reference material tried to swipe up/down and left/right to change chapter
U6	• Thought the creation of parcel would be done by pressing points on map directly without pressing plus FAB first *
	• Said the dropdown arrow was not very perceptible in reference material view

Table 5.4: Commentaries about each user

5.5   Recommendations

After collecting and analysing data from the results of the test, the facilitator's notes and the videos recorded during each session it was possible to formulate the following recommendations in table 5.5:

Issue	Recommendation
Scrolling — After conducting the test it was possible to see that some of the guidelines mentioned in section 4.3 were quite helpful to inform the design of the hi-fi prototype but they were not all strictly followed and because of this some of those issues still occasionally arose. This is an example of that, some participants had a hard time realising that scrolling was possible even following the scrolling guideline provided by Material. This happened because the device used while develop the design and the device used during the tests had different screen resolutions.	To combat this, providing a scrollbar on the screen could help to inform the users scrolling was possible or making sure, that with different screens resolutions the guideline of showing content overflow would be effective.
Buttons — For the less experienced users clicking smaller buttons or buttons with a smaller or not defined touch area proved to be hard.	If not constricted by other element on the UI, button's touch area should be larger than the Material's default area.
Mapping plot — Some users thought the creation of parcel would be done by pressing points on the map directly, without having yo press the plus FAB first.	This was actually something that was taken into account when designing. In order to prevent the user clicking on a plot while trying to map a new one, it was necessary to add a button to allow the user to map a new plot. A probable reason for this issue was that either people did not realise a FAB add button was available (due to it being green and the map behind having a majority of green tones) or they did not associate the symbolism of the plus icon with mapping a plot. A way to overcome this would be to change the FAB colour to the secondary colour (orange) for it to stand out and/or to change the icon to a pencil or even add a label to it. This should be applied to other interfaces in order to provide consistency.
Treatments' Calendar — Some users mixed up the treatment's starting date with the day the treatment was scheduled to be applied.	In order to avoid this mix-up the treatment's starting date should be omitted from the calendar view and only if the user opened the treatment this information would be provided.

Icons — Some of Material's icons proved to be too abstract for some users, especially the "layers" icon in the map view, even though it is also used in other popular Google mobile apps such as Google Maps.	As mentioned in section 4.3 icons should be culturally sensitive and not very abstract. Therefore an activity, for example, card sorting could help to inform designers on what icons farmer easily recognize and the symbolism they provide.
Heatmap — Most users were not familiar with the concept of a heatmap, therefore they assumed it meant to view the temperature that plot.	To combat this misconception this functionality should be presented in the Introduction screen.
Automatic Count — The grey area of uncertainty on the automatic count functionality was not easily understood by some users.	Providing a help dialog on the first times the user used this functionality would allow to inform the user about what the grey area means and about what the user should do next.
Reference Material — Most users had a hard time understanding where they could find information about trap's placement	This issue originated probably due to an incorrect task formulation. The task made the assumption that the farmer was used to deal with the grapevine moth and that he was also familiar with concepts related to prevention and control of pests. Besides this users had difficulties viewing the arrow on the dropdown button. This issue should be tackled and an improvement to this interface would be to have Material card stacked, simulating a book and allowing the user to swipe left/right or clicking on arrows to navigate through the different chapters. Another issue was that none of the users realised that the search option was available, this could possibly be overcome by providing a spotlight walkthrough on each main functionality for first time users.

Table 5.5: Recommendations

5.6 Guidelines

Taking into account all the information mentioned above here is a list of guidelines for designing for similar target-users.

- **"First time users"** — Most farmers said that if they experimented or had the help from someone they would feel more confident using the system and that it would be a factor that would influence their technology acceptance. For first time users I would suggest providing

a quickstart model [1]. Also providing help dialogs could be beneficial for more complex tasks.

- **"Buttons"** — Provide large touch target areas that are not nearby other touch areas. Delimited buttons seemed to be more recognizable than buttons without borders around. Avoid Material's flat buttons, if needed, provide a simple thin black border around the button area.

- **"Gestures"** — Provide buttons for multi-finger gestures because some users aren't aware of those functionalities (e.g. zoom magnifier on map). In addition providing alternative ways to perform simple gestures, like swiping, using arrows should be provided in some cases. Also be aware that some users not that familiar with touch screens will perform long-presses involuntarily, so try to avoid that type of gesture.

- **"Colour"** — It is important to, not only, take special attention to colour contrast when talking about elements in components, but also to pay attention to how colours on the interface compare to each other in terms of what elements are most prominent. For example, if using FABs, make sure that they are a colour that is very distinctive from other colours on the interface.

- **"Graphics"** — The use of graphical symbols and photos seemed to translate very well with all users. If possible use pictorial representations to assist and encode information.

- **"Icons"** — It is important to test with the target-users icons and the symbolism associated with them.

- **"Navigation"** — Keep the app's navigation simple by providing more sequential tasks.

- **"UI Components"** — Material's components seemed to not pose many problems for smartphone owners but for those who weren't familiar with other apps using Material's guidelines and components some issues arose. The components that should be avoided are the ones that require the user to be aware of actions that are not explicitly informed using the component. For example bottom navigation, if possible, should be preferred over a navigation drawer.

5.7 Summary

From a usability test with six winegrowers, with different profiles, it was possible to come to conclusions relating technological acceptance and user needs. Different metrics relating to the system's efficiency and efficacy were analysed and also relating to satisfaction. Commentaries and recommendations were also given based on this data.

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[1] https://material.io/guidelines/growth-communications/onboarding.html#onboarding-quickstart

Chapter 6

Conclusions and Future Work

6.1 Contribution

The aim of this study was to develop and adapt a mobile solution based on farmers' needs and context of use. To do so an in-depth research was conducted following a user centred design methodology. This allowed to discover several areas of opportunity for ICT solutions for Viticulture in the Douro region. This study hopefully marks the beginning of more projects related to mAgri solutions for rural areas in Portugal and will help inform the design of those systems when it comes to farmer-computer interaction.

6.2 Challenges

By far the main challenge in this research was the dependency on other people and organizations to provide knowledge, because the subject area of this study was so far off from my areas of study. Time and bureaucratic constraints made it difficult to follow an iterative development that is so crucial to the user centred design methodology. Looking back, having input from real farmers since the earlier stages would have been very beneficial.

6.3 Future Work

Firstly, as previously said, redesigning the prototype according to the recommendations given and performing iterations of tests with farmers would be the future work developed. The natural step after that would be to implement and deploy the application and to do so it would be necessary to construct a prediction model for pests and diseases in Portugal's vineyard. It would also be relevant to investigate on how computer vision solutions would allow to perform automatic count of insects in traps.

Conclusions and Future Work

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            ture   usage   and   big   agriculture   data | agricultural   economics.
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Appendix A

Market Analysis

SmartAgri Crop
by Global CyberSoft (Vietnam) JSC

age	*installs*	*languages*
February 2017	**10+**	**English Vietnamese**
last update	*rating*	*top ranking*
2/5/17	**5.00** 2	-
location	*price*	*categories*
Vietnam*	**Free**	**Farm Management Apps**

Agriculture Manager Cash Flow
by skaliotisdev

age	*installs*	*languages*
May 2016	**5+ thousand**	**English Filipino French Greek Indonesian Portuguese Spanish**
last update	*rating*	*top ranking*
2/3/17	**4.29** 79	-
location	*price*	*categories*
Greece*	**Free**	**Farm Management Apps**
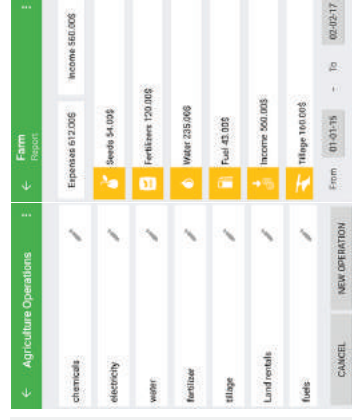
Farm Sage :: Farm Management
by Giraffe Revolution

age	*installs*	*languages*
March 2014	**1+ thousand**	**English**
last update	*rating*	*top ranking*
1/16/16	**3.81** 26	-
location	*price*	*categories*
-	**Free + In-app**	**Farm Management Apps**

* in Location means the developer's origin and not necessarily the target country

Agrivi
by Agrivi

referenced in papers

age — June 2016
installs — 1+ thousand
languages — English
top ranking — -
categories — Farm Management Apps, Weather Apps

last update — 10/24/16
rating — 4.53 / 19
price — Free
location — -
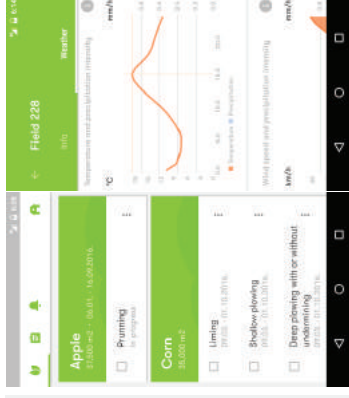
agrofarm
by Ilias Lamprou

age — May 2014
installs — 10+ thousand
languages — English, French, Greek
top ranking — -
categories — Farm Management Apps

last update — 2/20/17
rating — 4.47 / 159
price — Free
location — -
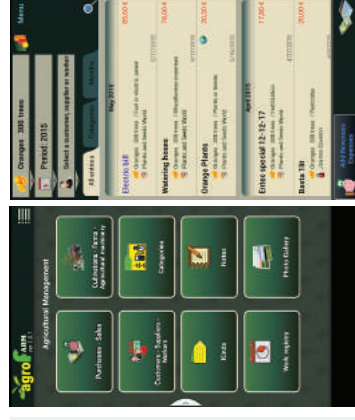
AgriApp
by Agriapp

referenced in papers

age — September 2014
installs — 100+ thousand
languages — English, Hindi, Kannada, Marathi, Tamil, Telugu
top ranking — -
categories — Learning and Reference Apps

last update — 12/9/16
rating — 4.24 / 1822
price — Free
location — Cambodia
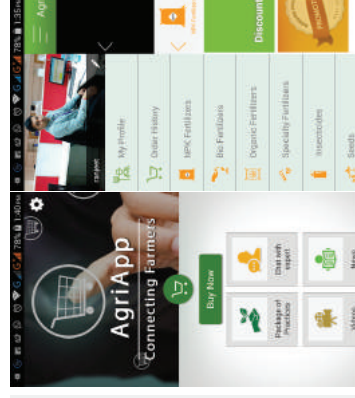
AgriSync
by AgriSync Inc

age May 2015	**installs** 500+	**languages** English
last update 3/13/17	**rating** 4.83 / 6	**top ranking** -
location -	**price** Free	**categories** Learning and Reference Apps

ID Weeds
by University of Missouri - Extension Division

age March 2016	**installs** 10+ thousand	**languages** English
last update 3/31/16	**rating** 3.5 / 14	**top ranking** -
location -	**price** Free	**categories** Learning and Reference Apps

GreenAgric
by tanzDevs

age October 2016	**installs** 1+ thousand	**languages** English Swahili
last update 2/16/17	**rating** 4.51 / 35	**top ranking** -
location Tanzania*	**price** Free	**categories** Learning and Reference Apps

Diseases and Pests Apps

Plantix
by PEAT

age
June 2015

last update
2/12/17

location
Germany*

installs
50+ thousand

rating
4.38
322

price
Free

languages
English

top ranking
Switzerland

categories
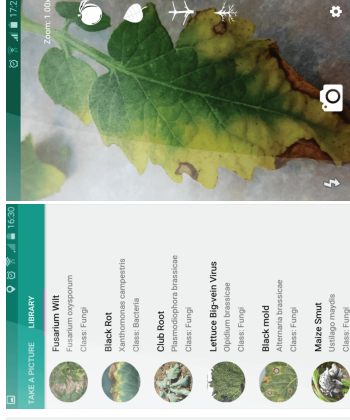
Agricultural Compendium
by Agrimind Apps

age
October 2015

last update
10/14/16

location
Brazil*

installs
100+

rating
2.93
30

price
$9.99 + In-app

languages
Portuguese

top ranking
Brazil

categories

Croprotect
by Ether Creative

referenced in papers

age
November 2015

last update
4/14/16

location
UK*

installs
100+

rating
3.67
3

price
Free

languages
English

top ranking
-
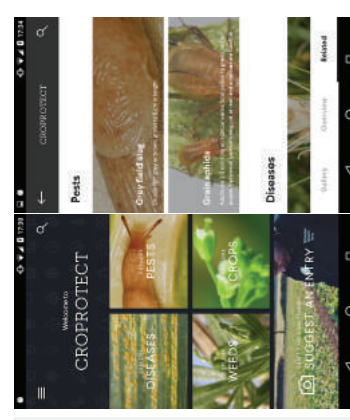
categories

Plantwise Factsheets Library
by CABI

(1) *Afghanistan, Bangladesh, Barbados, Bolivia, Brazil, Burkina Faso, Cambodia, China, Democratic Republic of Congo, Costa Rica, Ethiopia, Ghana, Grenada, Honduras, India, Jamaica, Kenya, Malawi, Mozambique, Myanmar, Nepal, Nicaragua, Pakistan, Peru, Rwanda Sierra Leone, Sri Lanka, Tanzania, Thailand, Trinidad and Tobago, Uganda, Vietnam, Zambia*

(2) *Bengali, Chichewa, Chinese, Dari, English, French, Khmer, Kinyarwanda, Nepali, Portuguese, Quechua, Sinhalese, Spanish, Swahili, Tamil Thai*

age February 2014	*installs* 1+ thousand	*languages* Various(2)	*categories*
last update 10/19/16	*rating* 4.34 / 44	*top ranking* -	
location Various(1)	*price* Free		**Diseases and Pests Apps**
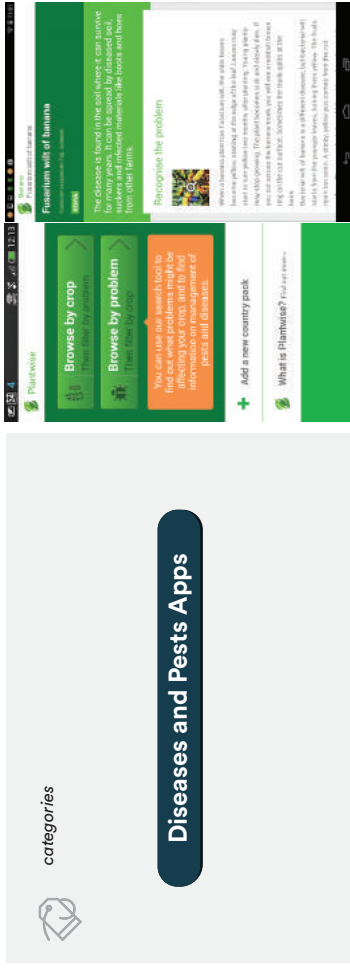
Doodo
by Doodo technology inc.

age November 2016	*installs* 100+	*languages* English	*categories*
last update 12/26/16	*rating* 4.45 / 22	*top ranking* -	
location -	*price* Free		**Diseases and Pests Apps**
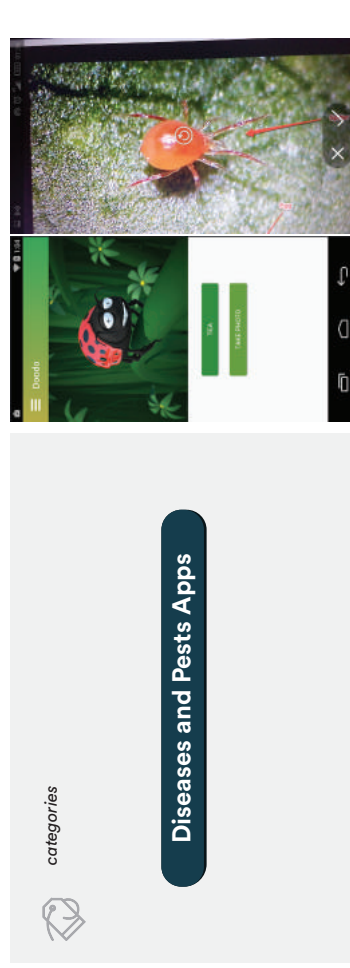
AgroStar - Agriculture App
by Ulink Agri-Tech Pvt. Ltd.

age March 2016	*installs* 50+ thousand	*languages* English Gujarati Hindi Marathi	*categories*
last update 2/23/17	*rating* 4.36 / 949	*top ranking* India	
location India	*price* Free		**Agriculture Information Apps**
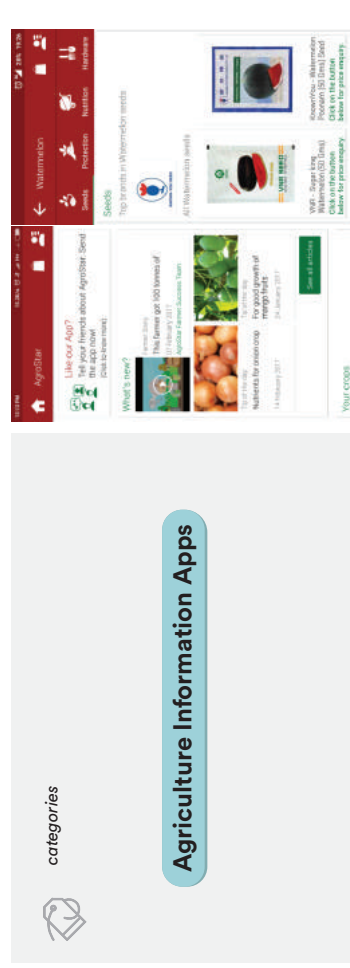
Way2ABI Agri FBI
by Way2Agribusiness India Pvt Ltd

age
November 2015

last update
11/14/16

location
India

installs
1+ thousand

rating
4.60
42

price
Free

languages
English
Kannada

top ranking
-

categories
Market Data Apps

iFarm Mobile
by iFarm Zimbabwe (Private) Limited

age
November 2016

last update
2/19/17

location
Zimbabwe

installs
100+

rating
4.20
5

price
Free

languages
English

top ranking
-

categories
Business Apps
Weather Apps

Ag Guardian
by Ag Guardian, LLC

age
December 2015

last update
1/1/16

location
-

installs
100+

rating
5
1

price
Free

languages
English

top ranking
-

categories
Business Apps

GPS Fields Area Measure
by Studio Noframe

age
December 2013

installs
1+ million

rating
4.42
27044

price
Free

last update
9/16/16

location
-

languages
Various[1]

top ranking
USA
Brazil
France
Spain
Germany
Indonesia
India
Mexico
Switzerland
Netherlands

categories
Field Mapping Apps

(1) Afrikaans, Arabic, Bulgarian, Catalan, Chinese (simplified), Croatian, Czech, Dutch, English, Finnish, French, Galician, German, Greek, Hebrew, Hungarian, Indonesian, Italian, Korean, Latvian, Lithuanian, Norwegian (Bokmål), Norwegian (Nynorsk), Persian, Polish, Portuguese, Portuguese (Brazil), Romanian, Russian, Serbian, Slovak, Slovenian, Spanish, Spanish (Argentina), Spanish (Colombia), Spanish (Mexico), Swedish, Tamil, Thai, Turkish, Ukrainian, Urdu

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AgDNA
by AgDNA

age
November 2013

installs
1+ thousand

rating
3
53

price
Free

last update
6/24/16

location
USA*, Canada*
Australia*
New Zealand*

languages
English

top ranking
-

categories
Field Mapping Apps

FarmLogs
by AgriSight Inc.

age
August 2012

installs
10+ thousand

rating
4.2
325

price
Free

last update
3/8/17

location
USA*

languages
English

top ranking
-
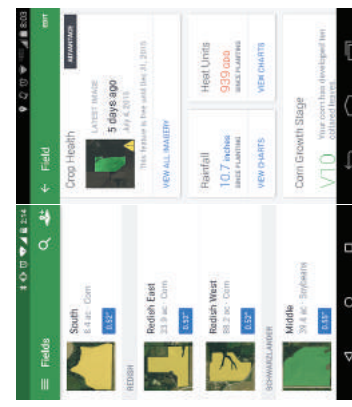
categories
Field Mapping Apps

eFarmer
by eFarmer B.V.

referenced in papers

age	**January 2012**
installs	**50+ thousand**
languages	**English**
top ranking	**France, Germany, Spain, Netherlands, Russia, Switzerland, Brazil**
categories	**Farm Management Apps**, **Field Mapping Apps**
rating	**4.41** / 868
last update	**2/23/17**
price	**Free + In-App**
location	**Netherlands***
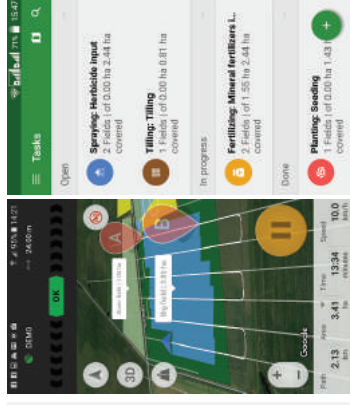
AgMobile
by Barchart.com

age	**October 2014**
installs	**10+ thousand**
languages	**English**
top ranking	**Saudi Arabia, Indonesia, Netherlands, Switzerland**
categories	**Weather Apps**, **Market Data Apps**, **Agriculture Information Apps**
rating	**4.41** / 176
last update	**2/26/16**
price	**Free + In-App**
location	**USA***
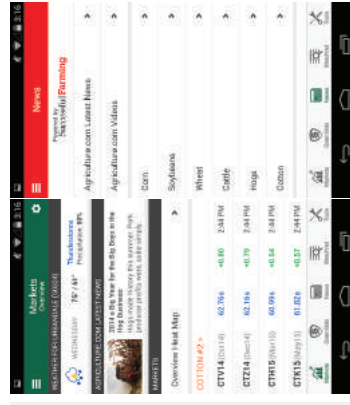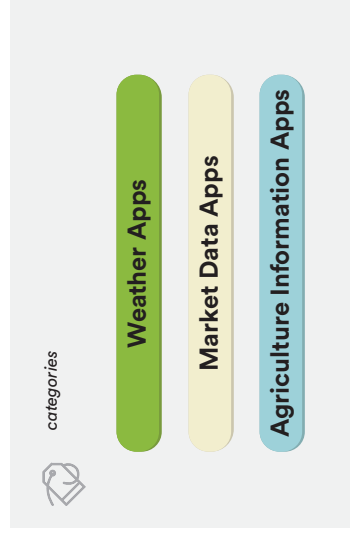
BayWa Agri-Check
by BayWa AG

age	**November 2013**
installs	**50+ thousand**
languages	**German**
top ranking	**Germany**
categories	**Weather Apps**, **Market Data Apps**
rating	**4.4** / 502
last update	**2/28/17**
price	**Free**
location	**Germany***

AgVault
by Sentera

categories
Farm Management Apps

top ranking
-

languages
English

installs
100+

rating
0
0

price
Free

age
January 2016

last update
1/26/16

location
USA*

RML Farmer - Krishi Mitr
by RML AgTech

categories
Weather Apps
Market Data Apps
Diseases and Pests Apps
Learning and Reference Apps

top ranking
India

languages
English
Hindi
Bengali
Gujarati
Kannada
Marathi
Punjabi
Tamil
Telugu

installs
100+ thousand

rating
4.32
7606

price
Free

age
May 2014
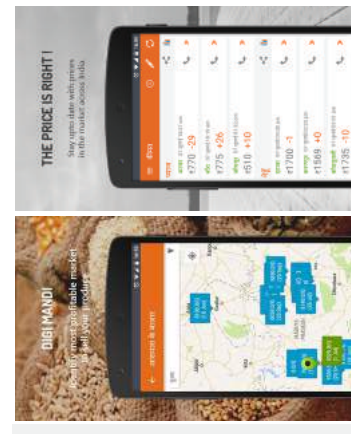
last update
2/2/17

location
India

AGRISCIENCE KRISHI
by Infinium Global Solutions

categories
Market Data Apps
Learning and Reference Apps

top ranking
India

languages
Hindi
Gujarati

installs
50+ thousand

rating
4.54
751

price
Free

age
March 2016

last update
3/23/17

location
India

KrushiKing कृषिकिंग
by Krushiking Agrotech Industries Pvt Ltd.

age
October 2015

installs
10+ thousand

last update
3/14/17

rating
4.38
1030

location
India

price
Free

languages
Marathi
English
Hindi

top ranking
India

categories
- Weather Apps
- Market Data Apps
- Agriculture Information Apps
- Learning and Reference Apps
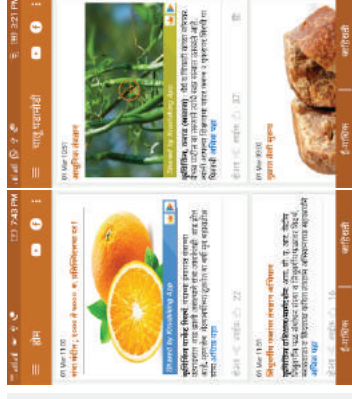
Huron Tractor
by AgDNA

age
February 2017

installs
5+

last update
3/4/17

rating
0
0

location
USA*, Canada*
Australia*
New Zealand*

price
Free

languages
English

top ranking
-

categories
- Farm Management Apps
- Field Mapping Apps
- Weather Apps
- Agriculture Information Apps
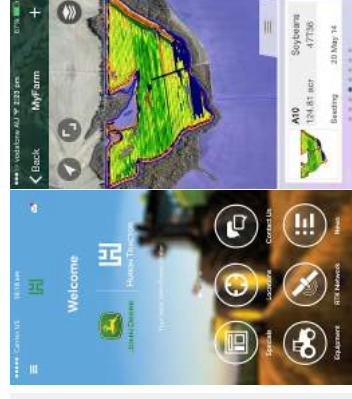
Bayer TurfXpert
by 2 dam creative

age
January 2013

installs
10+ thousand

last update
3/2/17

rating
4.07
103

location
UK

price
Free

languages
English

top ranking
-

categories
- Farm Management Apps
- Field Mapping Apps
- Weather Apps
- Diseases and Pests Apps
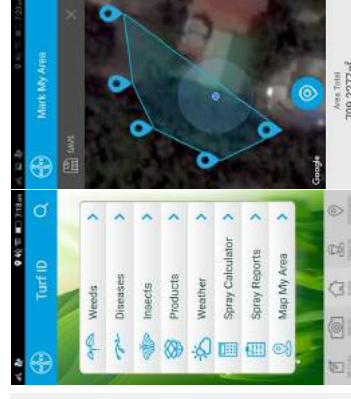
Khedut Mitra - GJ Agriculture
by FireTruck Enter10ment

- **age:** October 2016
- **installs:** 50+ thousand
- **rating:** 4.7 / 1896
- **last update:** 3/21/17
- **price:** Free
- **location:** India
- **languages:** Gujarati
- **top ranking:** India
- **categories:** Market Data Apps
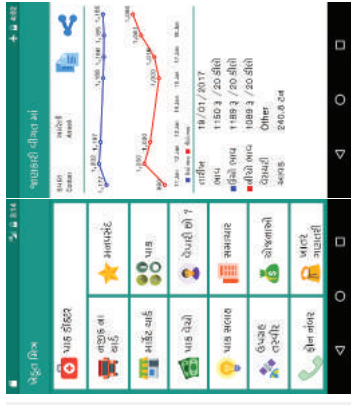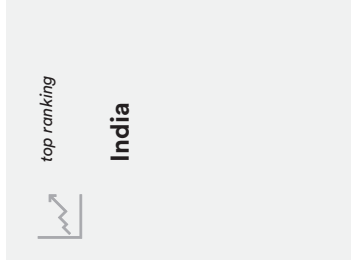
IFFCO Kisan- Agriculture App
by IFFCO Kisan

referenced in papers

- **age:** September 2015
- **installs:** 100+ thousand
- **rating:** 4.19 / 2070
- **last update:** 1/3/17
- **price:** Free
- **location:** India
- **languages:** English, Punjabi, Malayalam, Bengali, Odia, Marathi, Kannada, Telugu, Tamil, Gujarati, Hindi
- **top ranking:** India
- **categories:** Business Apps, Weather Apps, Market Data Apps, Agriculture Information Apps, Learning and Reference Apps

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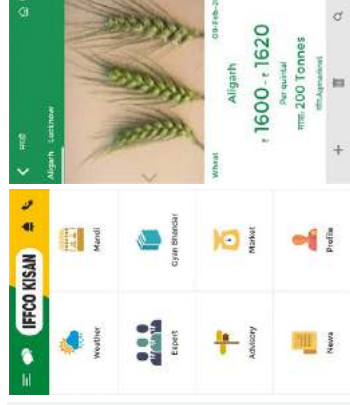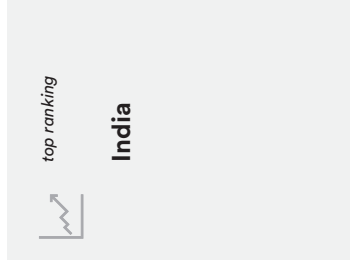
Agribolo - Agriculture App
by Agrilife Technologies Pvt. Ltd.

- **age:** April 2016
- **installs:** 5+ thousand
- **rating:** 4.88 / 436
- **last update:** 2/7/17
- **price:** Free
- **location:** India
- **languages:** English, Hindi
- **top ranking:** -
- **categories:** Weather Apps, Market Data Apps, Agriculture Information Apps, Learning and Reference Apps
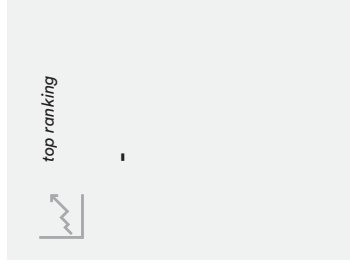
FINDINGS
market analysis
of android apps

4.1.1. Categories

Business Apps 3 · Weather Apps 10 · Field Mapping Apps 6 · Agriculture Information Apps 6 · Diseases and Pests Apps 7 · Learning and Reference Apps 9 · Market Data Apps 9 · Farm Management Apps 9
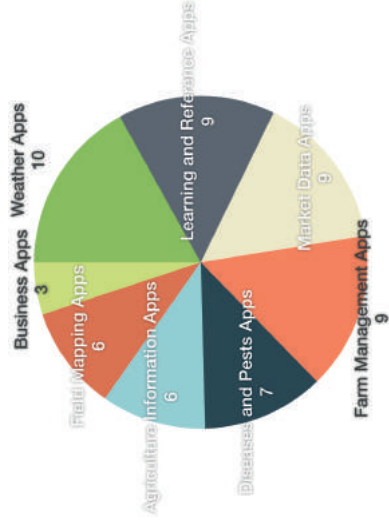
4.1.2 Locations
(that appear more than once)

India 9 · USA 5 · New Zealand 2 · Germany 2 · Canada 2 · Cambodia 2 · Brazil 2 · Australia 2
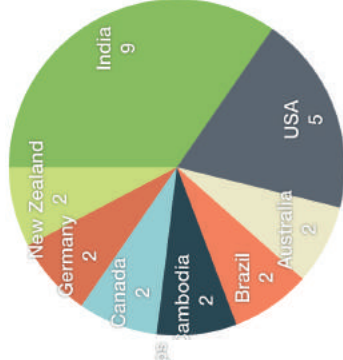
4.1.3. Languages
(that appear more than once)

English 29 · Hindi 7 · Gujarati 5 · Marathi 5 · French 4 · Kannada 4 · Portuguese 4 · Tamil 4 · Bengali 3 · Greek 3 · Spanish 3 · Telugu 3 · Chinese 2 · German 2 · Indonesian 2 · Punjabi 2 · Swahili 2

4.1.4. Age

2012 2 · 2013 4 · 2014 6 · 2015 8 · 2016 11 · 2017 2
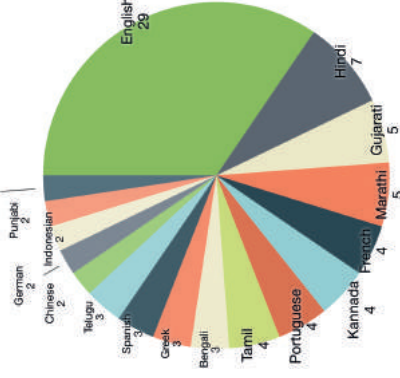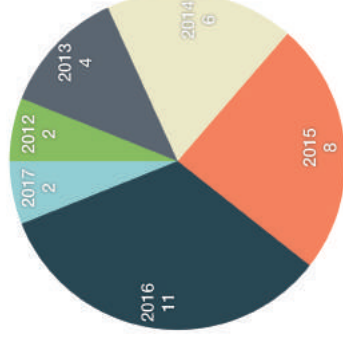
4.1.5. Monolingual VS Multilingual

Monolingual 19 · Multilingual 14
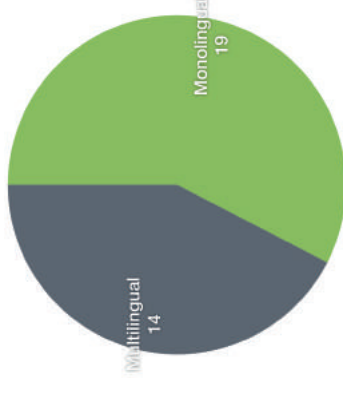
4.1.6. TOP 10 (Installs)

APP NAME	NUMBER OF INSTALLS
GPS Fields Area Measure	1+ million
RML Farmer - Krishi Mitr	100+ thousand
AgriApp	100+ thousand
IFFCO Kisan- Agriculture App	100+ thousand
AGRISCIENCE KRISHI	50+ thousand
eFarmer	50+ thousand
BayWa Agri-Check	50+ thousand
Plantix	50+ thousand
AgroStar - Agriculture App	50+ thousand
Khedut Mitra - GJ Agriculture	50+ thousand

4.1.7. TOP 10 (Rating)*

APP NAME	RATING	NUMBER OF RATINGS
Agribolo - Agriculture App	4.88	436
Khedut Mitra - GJ Agriculture	4.7	1896
AGRISCIENCE KRISHI	4.54	751
agrofarm	4.47	159
GPS Fields Area Measure	4.42	27044
eFarmer	4.41	868
AgMobile	4.41	176
BayWa Agri-Check	4.4	502
KrushiKing कृषिकिंग	4.38	1030
Plantix	4.38	322

* with more than 100 ratings

4.1.8. Most Versatile Apps

APP NAME	NUMBER OF CATEGORIES
IFFCO Kisan- Agriculture App	5
Agribolo - Agriculture App	4
Bayer TurfXpert	4
Huron Tractor	4
KrushiKing कृषिकिंग	4
RML Farmer - Krishi Mitr	4

Market Analysis

Appendix B

Categorizing Activity

B.1   Introduction

After collecting data about several apps released in the play store market it was necessary to assign categories to each app, depending on the functionalities provided or marketed by the developer. The "mother-categories" where defined by a previous study developed by Gary Woodill and Chad Udell, dating back to 2012. These study listed 8 different categories for mobile agriculture apps:

- **Information Apps** — These applications provide general information about agriculture, such as, laws and regulations, as well as information portals.

- **Business Apps** — Dedicated to the business aspect of the industry, they allow you to calculate investment estimates for materials or changes to the terrain.

- **Diseases and Pests Apps** — This category is intended for the prevention and control of diseases and pests. They can be informative as well as having the ability to recognize a disease through a photograph of the leaf.

- **Farm Management Apps** — They help with better management, such as personnel management, resources, etc.

- **Field Mapping Apps** — Through the GPS functionality it is possible to make a satellite mapping of the terrain, in order to measure and identify terrain areas.

- **Learning and Reference Apps** — They serve to educate and to be used as reference. They include dictionaries, encyclopedias, courses, etc.

- **Market Data Apps** — They allow access to information about the market, such as price of various products, sometimes updated in real time.

- **Weather Apps** — Dedicated to weather monitoring, they sometimes allow you to receive alerts of bad weather or natural phenomena.

B.2 Goal

The goal of this activity was to see what functionalities different people, with different backgrounds working in the HCI field, assigned to each category.

B.3 Participants

- **Participant 1** — Software engineer/Interaction designer

- **Participant 2** — Designer/Interaction designer

- **Participant 3** — Interaction designer with experience researching ICT4D solutions in under developed areas.

B.4 Methodology

The motivation and context of this dissertation were explained to the participants and right after, the introduction and goal of this activity were described. Then the participants had to rearrange post-its that were already placed randomly in a wall (see Fig. B.1). The instructions given were: the "mother-categories" could also be rearranged, for example, they could be put together, thrown out or placed in a different level. These rules also applied to the functionalities and if the user defined a functionality as transversal he could place that post-it in a different group. Functionalities could also be duplicated/repeated in different categories if the user wanted to do so.
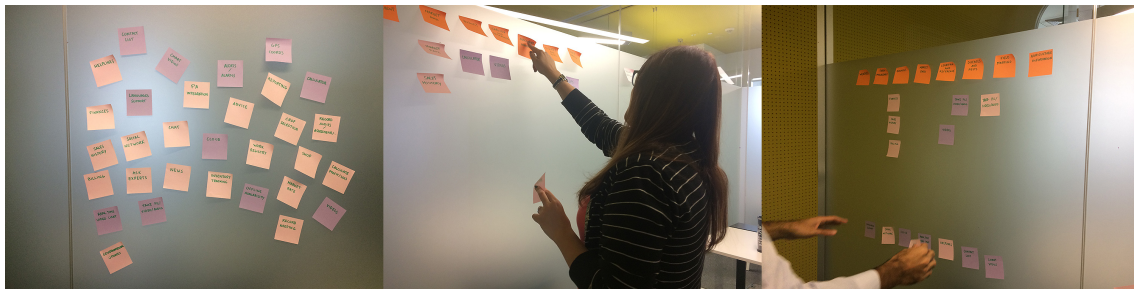
Figure B.1: Activity Setup

B.5 Findings

B.5.1 Participant 1

Figure B.2: Categorizing by Participant 1
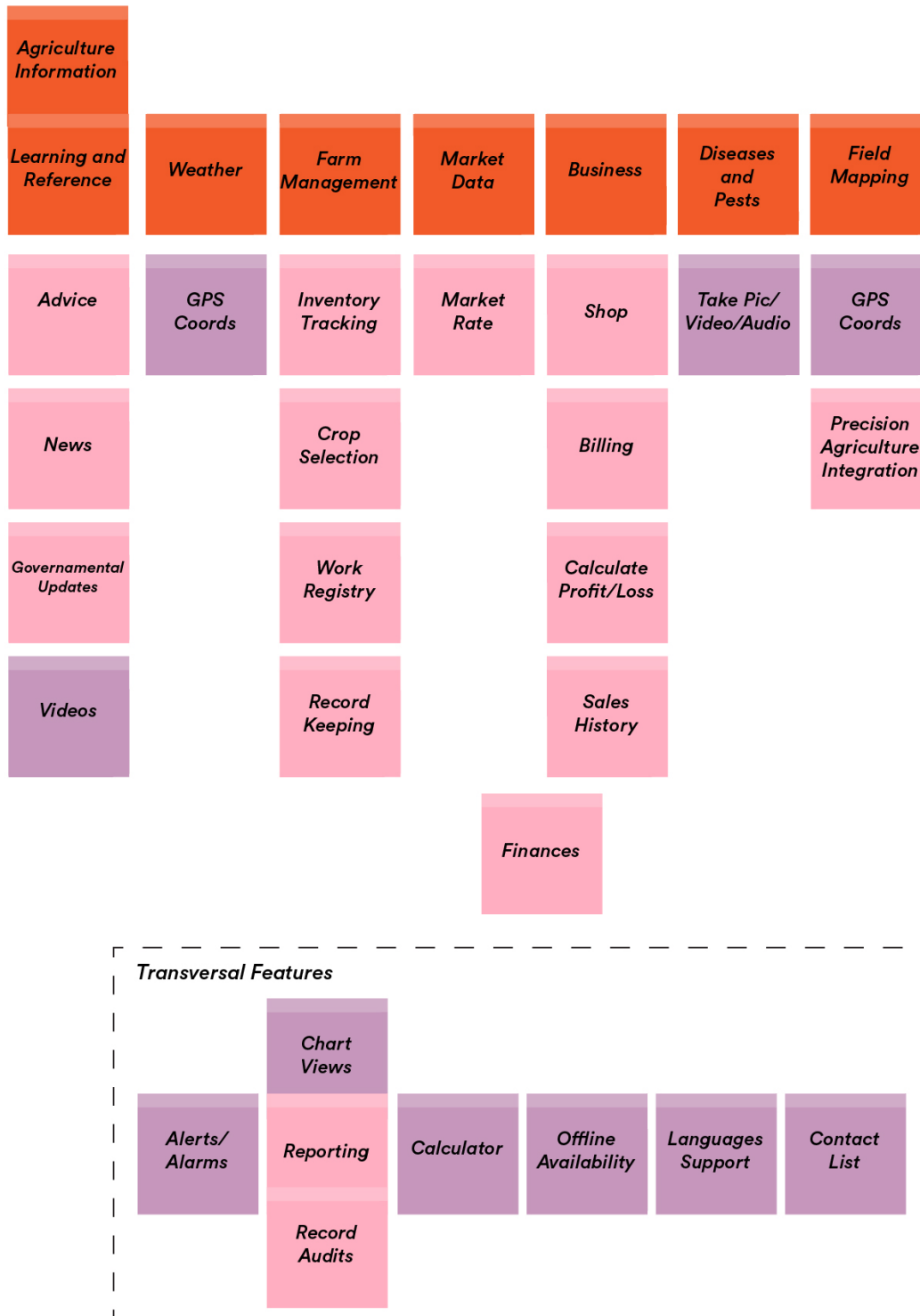
B.5.2 Participant 2

Figure B.3: Categorizing by Participant 2
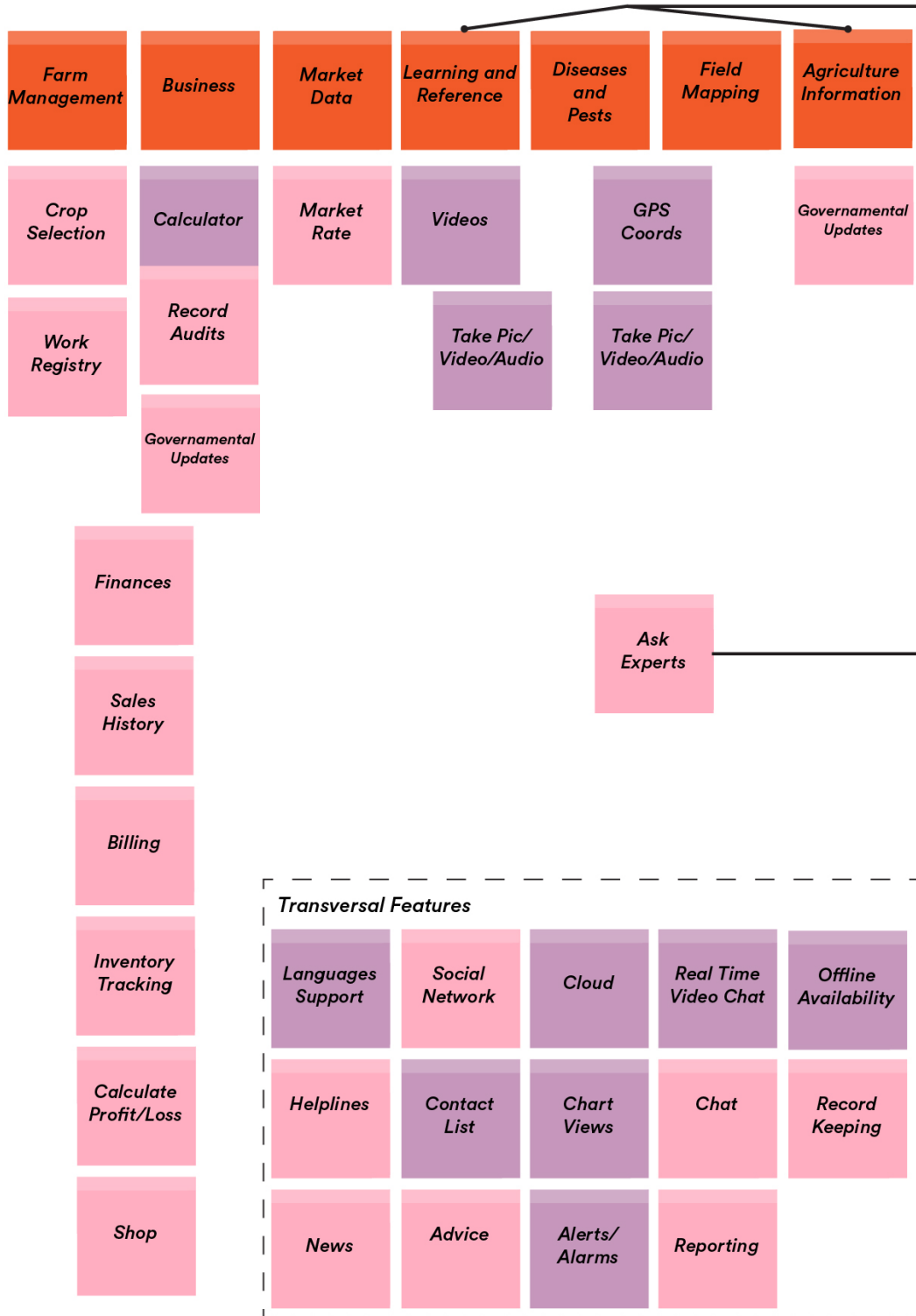
B.5.3 Participant 3

Figure B.4: Categorizing by Participant 3

B.6 Conclusion

These are the functionalities that at least two participant attributed to the same category.
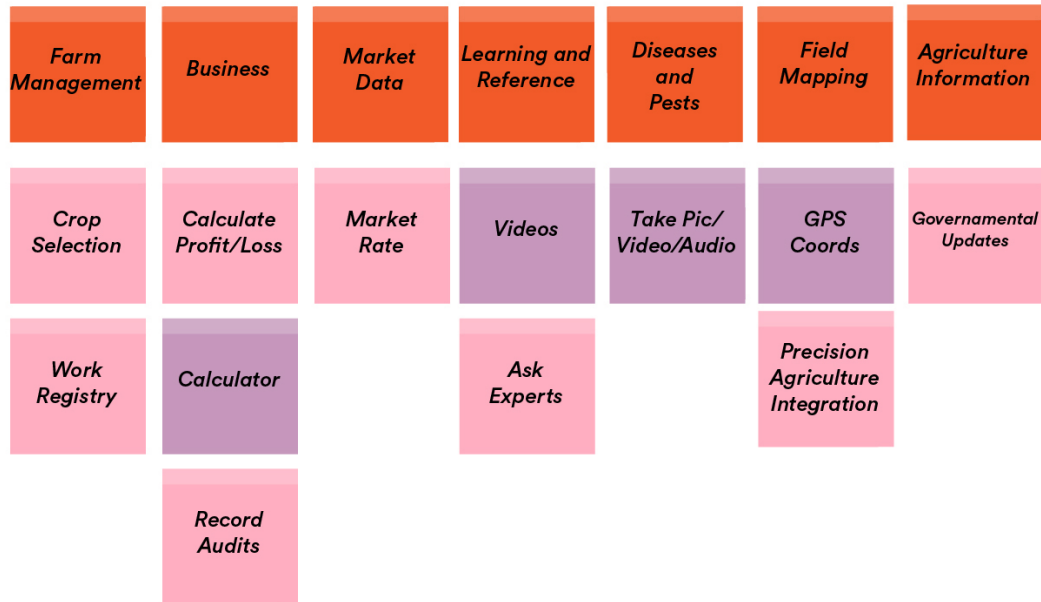
Figure B.5: Activity conclusion

It can be concluded that for different people, even working in the same field but with different professional backgrounds, different functionalities can be attributed to different categories. This can be a result of lack of understanding about the mother-categories or the functionalities.

This activity informed the attribution of categories to the updated applications study described in 4.1.1.

Appendix C

Statistical Data - Portugal and Douro Region

C.1   People and Society

- **Population:** 10,833,816 (July 2016 est.)

- **Languages:** Portuguese (official), Mirandese (official, but locally used)

- **Religions:** Roman Catholic 81%, other Christian 3.3%, other (includes Jewish, Muslim, other) 0.6%, none 6.8%, unspecified 8.3%

- **Population pyramid:**
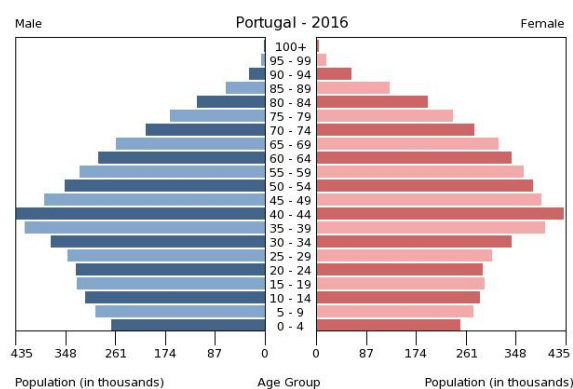
Figure C.1: Population pyramid [1]

- **Employment rate, persons aged 20-64:**
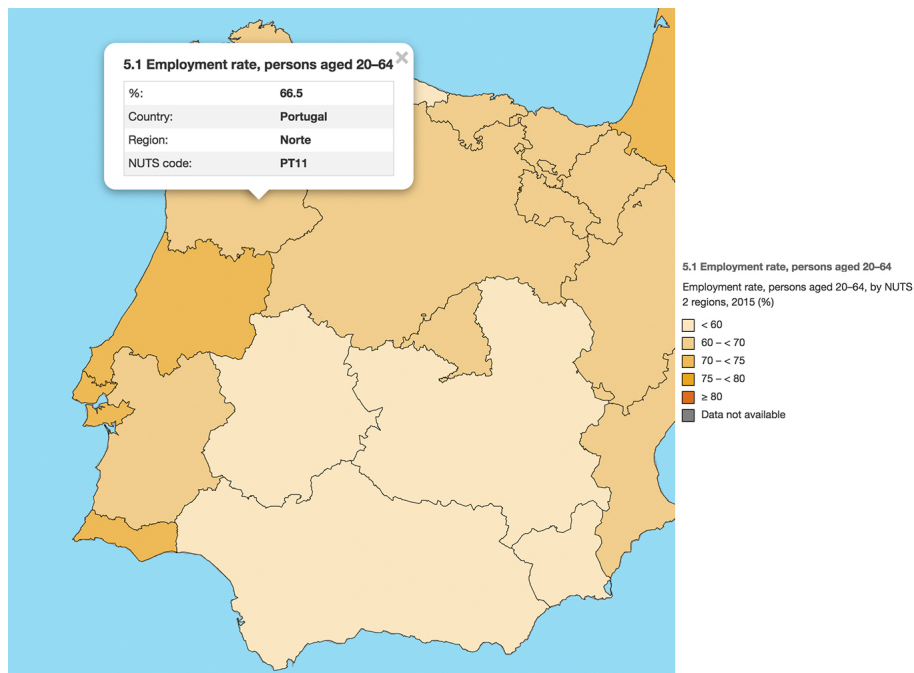
Figure C.2: Employment rate, persons aged 20-64

- **Working age population:**
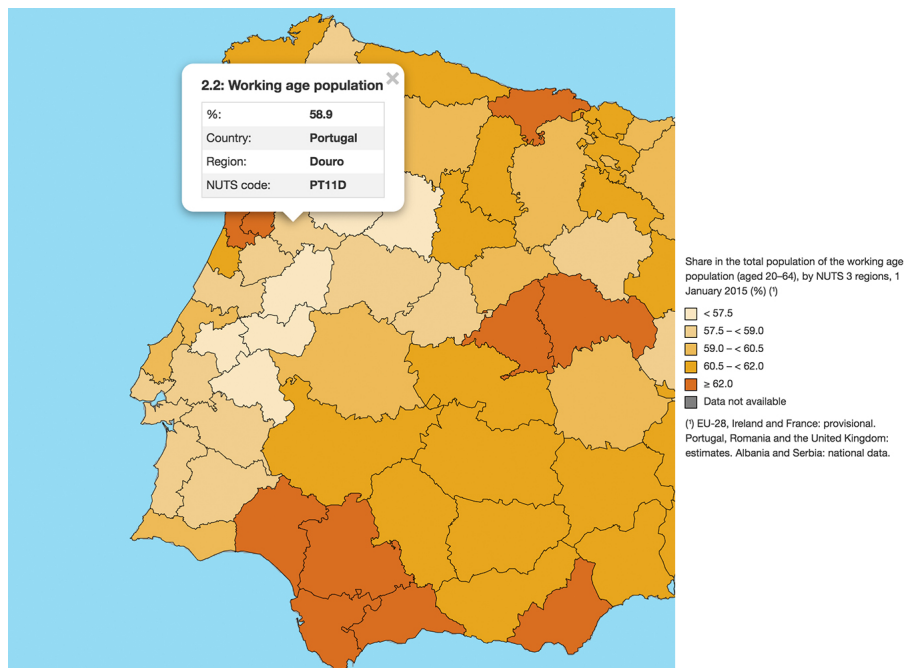
Figure C.3: Working age population

C.2 Education

- **Literacy:**

  Definition: age 15 and over can read and write

Total population	95.7%
Male	97.1%
Female	94.4%

Table C.1: Literacy Rate [2]

Place of residence (City, NUTS - 2002)	Illiteracy rate (%) by Place of residence (City, NUTS - 2002); Decennial
	Data reference period
	2011
	%
Portugal (cidades)	3,34
Continente (cidades)	3,27
Norte (cidades)	3,04
Douro (cidades)	3,74
Lamego	3,16
Peso da Régua	5,07
Vila Nova de Foz Côa	7,00
Vila Real	3,01
Tarouca	4,94
Centro (cidades)	3,26
Lisboa (cidades)	3,12
Alentejo (cidades)	5,24
Algarve (cidades)	3,60

Illiteracy rate (%) by Place of residence (City, NUTS - 2002); Decennial - Statistics Portugal, Population and housing census - 2011

Figure C.4: Iliteracy Rate [3]

[2] https://www.cia.gov/library/publications/the-world-factbook/geos/po.html
[3] https://www.ine.pt

- **Share of early leavers from education:** "Share of young people aged 18–24 who were early leavers from education and training, by NUTS 2 regions, 2015 (%)."
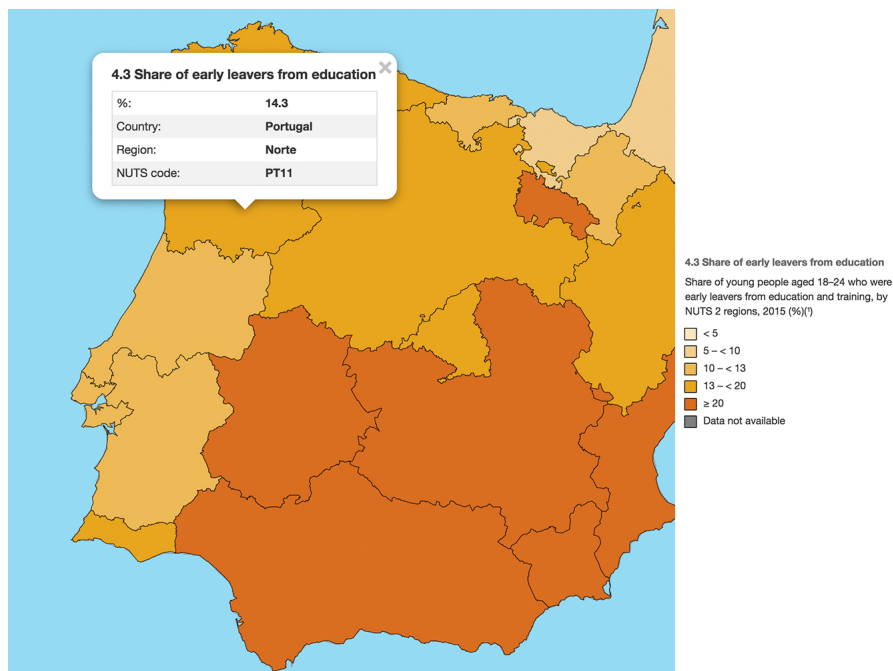
Figure C.5: Share of early leavers from education

- **Share of persons with tertiary education:** "Share of persons aged 30–34 with tertiary education (ISCED levels 5–8) attainment, by NUTS 2 regions, 2015 (%)"

Figure C.6: Share of persons with tertiary education

C.3   Information Society

- **Broadband availability:**
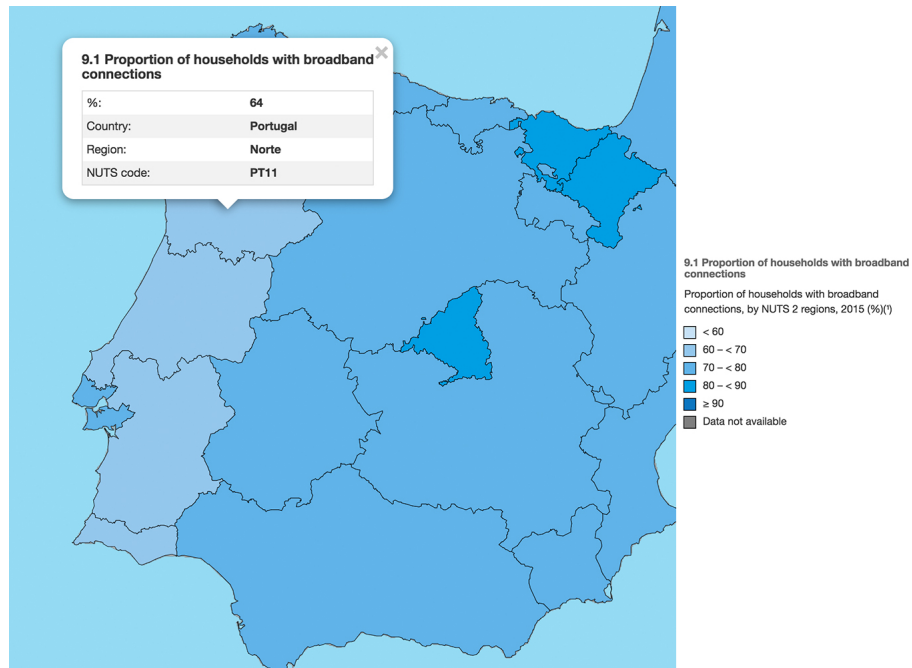
Figure C.7: Proportion of households with broadband connections

- **Internet usage:**
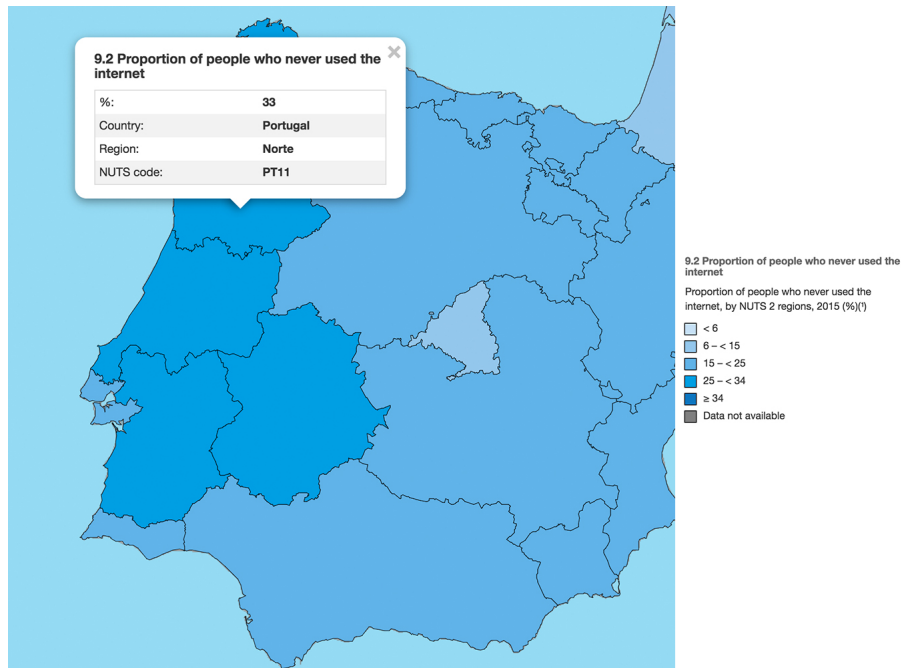
Figure C.8: Proportion of people who never used the internet

All this data was collected from The World Factbook by the Central Intelligence Agency[4], from Eurostat[5] and from Statistics Portugal.

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[4] https://www.cia.gov/library/publications/the-world-factbook/geos/po.html
[5] http://ec.europa.eu/eurostat/statistics-explained/index.php/Eurostat_regional_yearbook
[5] https://www.ine.pt

Appendix D

Script of Interview

D.1 Introduction

Hi my name is Maria Marques and I am a student at the Faculty of Engineering at the University of Porto. I am currently developing my master thesis at Fraunhofer Portugal. Fraunhofer is a private non-profit association founded by Germany's largest applied research organization. I've also come accompanied by Eduardo Pereira, who is a researcher in the Human Computer Interaction field at Fraunhofer.

Fraunhofer Portugal is dedicated to researching how to improve the living conditions of people through technological solutions capable of facilitating access to information and communication technologies. There are two specific groups that are the focus of that research, elderly people and populations in remote areas or in developing countries. In this case, the focus are farmers in rural areas of Portugal. We intend to increase their productivity and production through the development of a mobile application for smartphones.

In order to better pay attention to you, I would like to ask for your permission to record audio. It is purely for the purpose of research and will not be used for commercial or promotional purposes. And I will also ask you to fill out a short questionnaire [deliver questionnaire in **??**]. I would like you to read and sign the consent [deliver the consent form in D.4].

Do you have any questions before we start?

D.2 Warm-up

- Ask the participants to introduce themselves. What is your name, age, and what do you do?

- How is a daily routine? Who do they work with and deal with directly?

- Who do they trust/influences their decision making? And who is dependant on them to make decisions?

- Do you own a phone? What type of phone? What do they use it for?

D.3 General questions

In order to increase the productivity and production of the farmer in rural areas and focusing on the factors that lead to a good harvest: in grape quality and quantity as well as in the prevention and control of diseases and pests.

D.3.1 For Farmers

- What is your work process? Before, during and after harvesting.

- Regarding the forecasting of production, what is your role and what is not performed by you?

- Regarding the quality of the grape, what is your role and what is not performed by you?

- How do you inform yourself of pests or diseases in the area? And about treatment?

- What are your main goals? Optimize production? Better quality grapes?

- What frustrates or discourages you?

- Do you imagine yourself using a mobile phone on a daily basis in the field?

D.3.2 Other stakeholders

- In your opinion what are the farmers' main goals within these themes?

- And the main problem areas or concerns?

- How could your work be facilitated using a mobile app?

- How could a smartphone be integrated into the daily routine of a farmer?

D.4   Consent Form

![Fraunhofer PORTUGAL logo]

CONSENTIMENTO PARA PARTICIPAÇÃO EM INVESTIGAÇÃO

No âmbito do projeto «EyesOnFarm», estamos a realizar um estudo com o objetivo de desenvolver uma solução para dispositivos móveis, focada em agricultores da vinha, na zona do Douro. Com essa solução pretendemos aumentar a produtividade e produção dos agricultores, através de uma investigação em que estes se encontram no centro do processo de desenvolvimento.

Para efeitos de pesquisa, iremos proceder à recolha de dados sociodemográficos e à gravação audio desta entrevista.

Gostaríamos de contar com a sua participação. A participação não envolve qualquer prejuízo ou dano material e não haverá lugar a qualquer pagamento. Os dados recolhidos são confidenciais. A *Fraunhofer AICOS Portugal* tomará todas as medidas necessárias à salvaguarda e protecção dos dados recolhidos por forma a evitar que venham a ser acedidos por terceiros não autorizados.

A sua participação é voluntária, podendo em qualquer altura cessá-la sem qualquer tipo de consequência. Agradecemos muito o seu contributo, fundamental para a nossa investigação!

O participante:

Declaro ter lido e compreendido este documento, bem como as informações verbais fornecidas e aceito participar nesta investigação. Permito a utilização dos dados que forneço de forma voluntária, confiando que apenas serão utilizados para investigação e com as garantias de confidencialidade e anonimato que me são dadas pelo investigador. Autorizo a comunicação de dados de forma anónima a outras entidades que estabeleçam parceria com a Fraunhofer AICOS Portugal para fins académicos e de investigação científica.

Nome do participante: _____

Assinatura do participante: _____

Data ___ / ___ / _____

Investigador responsável:

Nome: Eduardo Pereira   Telefone: +351 22 0430 363   E-mail: eduardo.pereira@fraunhofer.pt

Script of Interview

Appendix E

Pests and Diseases in Vineyard

TRAÇA DA UVA
praga

- "É considerada a principal praga das vinhas da Região Demarcada do Douro pela importância económica dos prejuízos que origina, já que para além dos estragos directos provocados pelas lagartas, os estragos indirectos assumem particular relevo devido à instalação de podridões, em especial, da podridão cinzenta."

- É importante perceber o ciclo biológico da traça (diferentes estados de desenvolvimento nas três gerações).

- A nocividade da traça da uva está muito ligada às condições climáticas e microclimáticas do local onde se desenvolve.

- As estimativas do risco de cada geração indicam o início e o final do período de voo e portanto do período de postura.

Meios de proteção:

"CULTURAIS
- **Polvilhação** - De acordo com TORRES-VILA (1999) a traça da uva prefere efectuar posturas em cachos não polvilhados do que nos polvilhados (com enxofre, pó das estradas ou cal) embora no caso de não haver substracto, a postura se produza igualmente em ambos os locais.

- **Poda e condução da videira** - aconselham-se as que facilitem o arejamento dos órgãos frutíferos.

- **Desfolha** - para além de facilitar a penetração da calda nos cachos, a exposição directa dos ovos de traça aos raios solares acaba por provocar a sua dessecação.

- **Época de vindima** - a colheita dos cachos com lagartas que ainda não os abandonaram para pupar, pode reduzir a incidência da praga. Para além disso, a antecipação da vindima pode ser aconselhada no caso do risco de podridão cinzenta ser elevado.

TRATAMENTOS FITOSSANITÁRIOS
1 - Conhecer o modo de acção dos pesticidas
2 - Conhecer a persistência de acção
3 - Conhecer o intervalo de segurança
4 - Forma de aplicação

CONFUSÃO SEXUAL"

Estimativa de risco:

Armadilha de atracção sexual

"Os primeiros voos cicatrizam. É necessário proceder à captura de machos através de armadilhas de atração sexual para identificar o momento no qual se devem concentrar as estimativas de risco de cada geração. A armadilha é colocada ao nível dos cachos e numa parcela com historial de ataque."

Como instalar e acompanhar a armadilha sexual?

* A armadilha (armação + feromona + base de cola) deve ser colocada em meados de Abril numa parcela onde se tenham verificado problemas com esta praga em anos anteriores, mais ou menos no meio do talhão.

* A armadilha deve ser colocada entre duas cepas no segundo arame, ao nível onde no futuro se localizarão os cachos. Após a colocação da armação, abre-se a base de cola, verificando se esta se encontra espalhada de forma uniforme e, sem tocar na feromona com as mãos, coloca-se esta deitada no centro da base de cola. O conjunto (base de cola e feromona) deve ser colocado no interior da armadilha (ver Fig.1.)

* Semanalmente, retira-se a base de cola e, com a ajuda de uma pinça, removem-se os adultos devido ao facto do odor destes poder afugentar os adultos presentes na parcela, influenciando igualmente a eficácia da armadilha.

* Não tocar com as mãos na feromona, uma vez que resulta numa perda de eficácia desta.

* Os adultos recolhidos devem ser colocados a mais de 50 metros de distância da armadilha, registando-se o seu número no caderno de campo.

* A duração da feromona é geralmente de 6 semanas tendo que, findo esse período, proceder-se à sua substituição, assim como da base de cola.

CIGARRINHA VERDE
praga

- "Estes insetos picadores-sugadores alimentam-se perfurando e sugando o conteúdo celular das nervuras das folhas."

- "A sua atividade alimentar resulta na deformação da superfície das folhas, sobretudo as mais jovens, alteração na coloração e morte de tecidos foliares, o que tem implicações na quantidade e qualidade da produção e na migração de reservas para o ciclo vegetativo seguinte."

- "Ataques severos podem provocar a queda prematura das folhas, com exposição excessiva dos cachos ao sol."

- "No seu conjunto, as contagens da armadilha e as observações directas de ninfas nas folhas permitem-nos determinar a melhor data para efectuar determinado tipo de tratamento"

Estimativa de risco:

"Na vinha esta armadilha é usada para observar a evolução da curva de voo da cigarrinha verde (Empoasca vitis e Jacobiasca lybica) e da cicadela vectora da Flavescência Dourada (FD) (Scaphoideus titanus)".

"Tal como a armadilha sexual, as cromotrópicas apenas nos dão uma ideia da intensidade do voo e da altura do ciclo em que se encontra, não havendo relação directa entre as capturas e os estragos provocados pelas ninfas."

Armadilha cromotrópica para captura de adultos

Como instalar e acompanhar a armadilha cromotrópica?

* A armadilha deverá ser colocada por volta durante o mês de Abril de modo a interceptar os primeiros adultos provenientes dos locais de hibernação (arbustos de folha persistente)

* A armadilha é pendurada no 2º arame ao nível das folhas entre duas cepas. Retira-se o papel adesivo dos dois lados com cuidado. Deve afastar-se a vegetação em crescimento para esta não ficar aí agarrada e impedir o efeito de atracção da armadilha.

* Semanalmente a armadilha deve ser substituída e os adultos interceptados nos dois lados da armadilha devem ser contados. O seu valor deve constar das fichas de controlo presentes no caderno de campo.

* Nessa mesma ficha devem ser registados os resultados das contagens de ninfas/100 folhas, efectuadas ao longo do ciclo vegetativo da videira.

Meios de luta:

As medidas de luta cultural que influenciem os fatores de nocividade da praga (sensibilidade das castas, o vigor das cepas, stress hídrico da videira, etc.), bem como o fomento da limitação natural através do aumento da biodiversidade nas parcelas, são aspetos a ter em conta em proteção integrada. Contudo, atingido o nível económico de ataque, torna-se indispensável recorrer à luta química para combater com eficácia estes cicadelídeos. Na seleção de cada produto fitofarmacêutico a utilizar, deverá atender-se aos respetivos efeitos secundários."

"O recurso a armadilhas para captura de adultos e a contagem do nº de larvas presentes na página inferior das folhas desde o final da Primavera permitem quantificar as populações e,de acordo com os níveis económicos de ataque estabelecidos determinar as épocas de intervenção com insecticidas homologados."

INSETO VETOR DA FLAVESCÊNCIA DOURADA

praga/doença

"Scaphoideus titanus é o inseto vetor da doença "Flavescência Dourada".

Ao controlar o inseto, combatemos a doença, impedindo a sua transmissão. O inseto propaga-se por ovos que ficam na madeira da videira com dois ou mais anos. Os restos dessa madeira, resultantes da poda, deverão ser destruídos, o que permitirá baixar a população de S.titanus para o próximo ano."

"Flavescência dourada é a doença mais severa provocada por fitoplasmas que afeta a cultura da vinha, com grande impacte económico no setor vitivinícola (viticultores, viveiristas e produtores de vinho). Nas cultivares mais sensíveis conduz, rapidamente, à morte das plantas."

Estimativa de risco:

Igual à da cigarrinha verde As armadilhas cromotrópicas apenas nos dão uma ideia da intensidade do voo e da altura do ciclo em que se encontra, não havendo relação directa entre as capturas e os estragos provocados pelas ninfas."

Armadilha cromotrópica para captura de adultos

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* A armadilha deverá ser colocada por volta durante o mês de Abril de modo a interceptar os primeiros adultos provenientes dos locais de hibernação (arbustos de folha persistente)

* A armadilha é pendurada no 2º arame ao nível das folhas entre duas cepas. Retira-se o papel adesivo dos dois lados com cuidado. Deve afastar-se a vegetação em crescimento para esta não ficar aí agarrada e impedir o efeito de atracção da armadilha.

* Semanalmente a armadilha deve ser substituída e os adultos interceptados nos dois lados da armadilha devem ser contados. O seu valor deve constar das fichas de controlo presentes no caderno de campo.

* Nessa mesma ficha devem ser registados os resultados das contagens de ninfas/100 folhas, efectuadas ao longo do ciclo vegetativo da videira.

Meios de proteção:

"Não existindo meios de luta curativos contra os fitoplasmas, o controlo da doença passa pela utilização de material certificado nas plantações, combate ao vetor e utilização de variedades tolerantes às existentes. Impõe-se uma estratégia integrada de luta contra a doença da Flavescência dourada da videira, em que se utilizem todos os meios de luta disponíveis, cultural, química e biológica. O tratamento térmico dos materiais (45 minutos a 50º C) elimina o fitoplasma e as posturas do vetor. O arranque dos focos de infeção torna-se imprescindível."

MEDIDAS PROFILÁCTICAS

"- Utilização de material vegetal são (bacelos e garfos). Um factor determinante na introdução da doença na vinha;

- Arranque sistemático das cepas infectadas;
- Desvitalização e arranque das vinhas abandonadas;
- Queima da lenha da poda, sobretudo da madeira com mais de 2 anos."

MÍLDIO
doença

- "O míldio é uma das principais doenças da videira."
- "É provocada pelo fungo Plasmopara vitícola, que ataca todos os órgãos verdes da videira."
- "O míldio desenvolve-se em condições climáticas caracterizadas por temperaturas amenas, chuva e humidade relativa elevada. Normalmente as temperaturas acima dos 30°C são prejudiciais ao fungo."

Sintomas:

FOLHAS
- Manchas de óleo na página superior das folhas da videira
- Frutificações brancas na página inferior (conidióforos)
- Se as folhas ficaram secas, apresentam-se castanhas e quebradiças
- No Outono, podem surgir manchas necrosadas em mosaico

INFLORESCÊNCIAS
- Flores com bolor branco/acastanhado
- Inflorescência em báculo

CACHOS
- Pó branco a revestir a superfície dos bagos
- Cacho em báculo (rot gris): adquirem uma coloração escura e acabam por secar

Estimativa de risco:

O estudo da maturação dos oósporos é um método de estimativa de risco do início das infecções que permite determinar quando os oósporos estão maduros. Perante o nível de crescimento dos pâmpanos (superior a 10 cm), a temperatura superior a 10 °C, a importância e persistência das chuvas (pelo menos 10 mm durante um ou dois dias), segundo a rega dos três 10, podem existir condições favoráveis às infecções primárias (Aguiar, et al., 2001).

Meios de proteção:

LUTA CULTURAL

- Drenagem dos solos com elevada capacidade de retenção de água, para evitar a formação de poças de água.
- Eliminar os órgãos atacados
- Favorecer o arejamento das videiras através dos sistemas de condução e intervenções em verde.
- Evitar técnicas que conduzam a um excesso de vigor (castas, sistemas de condução, porta-enxertos e adubações).

OÍDIO
doença

- "O oídio é provocado pelo fungo Uncinula necator e os seus efeitos são visíveis nas folhas, nos pâmpanos novos e sobretudo nos cachos."
- "O tempo nublado e o ar com elevada humidade relativa são as condições favoráveis para o desenvolvimento do oídio."
- "Ataca todos os órgãos verdes da videira."

Estimativa de risco:

A estimativa de risco é efetuada de acordo com o conhecimento da sua biologia e epidemiologia.
É importante observar diretamente em campo e acompanhar o ciclo da doença como também completar com a informação emitida pela DRAP.

Fatores de nocividade	
Abióticos	• Acompanhar a evolução das condições meteorológicas (temperatura, humidade relativa, precipitação e radiação).
Bióticos	• Fase de desenvolvimento do patogénio • Resistência do patogénio a fungicidas • Inóculo presente nos sarmentos
Culturais	• Sensibilidade da casta (Tinta Roriz, Tinta Amarela, Malvasias, Gouveio...) • Estado fenológico (cachos visíveis e o período entre a pré-floração e o fecho dos cachos) • Sistema de condução da videira • Controlo de crescimento e vigor • Exposição à vinha • Drenagem do solo • Tipo de sistematização da parcela (patamares, vinha ao alto, tradicionais)
Económicos	• Vinha de encosta (declives das parcelas) • Fragmentação das parcelas e capacidade de intervenção (equipamentos)

Meios de proteção:

LUTA CULTURAL

Deverá ser realizada uma selecção cuidada das castas (se possível escolher aquelas que são mais resistentes ao oídio), porta-enxertos e do sistema de condução a implementar. Além disso, a poda deve permitir o arejamento e exposição à luz e se for necessário deverá ser realizadas intervenções como a desfolha ou a despampa. Na poda de Inverno as varas com cleistotecas visíveis devem ser eliminadas.

		MEIOS DE PROTEÇÃO
Luta cultural	Medidas indiretas	• Local da parcela, seleção material vegetativo certificado e optar por castas menos sensíveis e adaptadas ao local. • Sistematização do terreno, dando preferência à instalação de vinha ao alto ou patamares de um bardo (1 linha) permitindo o acesso a ambas as faces da videira e controle da vegetação no talude. • Controlar o vigor da planta, racionalizando as fertilizações e as regas. • Optar por um sistema de condução que permita ao cacho um bom arejamento e uma correta exposição à luz.
	Medidas diretas	• Destruir (retirar da parcela e queimar) as varas, folhas e sarmentos da poda com manchas. • Vigilância nos períodos de maior sensibilidade, cachos visíveis ao fecho do cacho. • Deteção e avaliação da intensidade das infeções primárias. • Promover uma correta orientação da vegetação por forma a promover o arejamento dos cachos (despampas, amparas, desfolhas...). • Tratamentos preventivos.

ESCORIOSE
doença

- "A escoriose é uma doença da vinha capaz de provocar importantes quebras de produção e que pode afectar a cultura desde a fase inicial do ciclo vegetativo."
- "Esta doença, que afeta os primeiros entrenós da vara, pode causar a morte de gomos da base levando à perda de produção e até à perda da vara. Na base das varas surgem fendas."

Meios de proteção:

LUTA CULTURAL

Podemos prevenir o aparecimento e a dispersão da doença, utilizando garfos sãos na enxertia, evitando o excesso de vigor das plantas e eliminando, pela poda, as varas com sintomas de escoriose, queimando-as de imediato.

Tomada de decisão:

A detecção de focos de escoriose na vinha (inóculo) e a previsão de ocorrência de chuva na fase inicial do ciclo vegetativo da videira (período de maior sensibilidade) justifica que, além das medidas de luta cultural, se recorra à luta química.

Estimativa de risco:

"A presença de sintomas nas folhas e especialmente nos sarmentos deve levar à determinação da intensidade de ataque da doença, na altura da poda, observando-se a presença de fendilhamentos e escoriações nas varas, de pontuações negras (picnídios) e de estrangulamentos na base dos sarmentos. Deste modo, será possível avaliar a importância do ataque e a distribuição da doença na vinha.

Para mais rigorosa avaliação da intensidade de ataque, escolher 10 cepas, ao acaso, na zona da vinha onde se detectaram sintomas na Primavera e Verão e determinar, na altura da poda, a percentagem do ataque correspondente à presença de sintomas nos quatro primeiros entrenós de todas as varas das 10 cepas."

Appendix F

Brainstorming Activity

F.1 Introduction

After interviewing and visiting various stakeholders in the winegrowing business it was time to assess the opportunities for development and decide which area the mobile solutions would tackle.

F.2 Goal

To come up with a user profile and ideas for a mobile android application relating to Viticulture in the Demarcated Douro Region.

F.3 Participants

The same participants of the Categorizing activity (Appendix B):

- **Participant 1** — Software engineer/Interaction designer

- **Participant 2** — Designer/Interaction designer

- **Participant 3** — Interaction designer with experience researching ICT4D solutions in under developed areas.

F.4 Methodology

The preparation of this activity was guided by the methods "Bundle Ideas" [1] and "Brainstorming Rules" [2] provided by IDEO.

- **Warm-up + Introduction** — the participants were made aware of what phase in the design process this activity fit in.

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[1] http://www.designkit.org/methods/28
[2] http://www.designkit.org/methods/30

- **Understanding the context** — during this time mainly concepts and information related to viticulture and relevant to the activity were presented.

- **Presentation of personas and scenarios** — in order to better present the findings from the research methods applied, scenarios and personas were presented, enabling the designers to get a better understanding of the possible users this solution would be designed for and their struggles.

- **Brainstorming activity** — during this period of time discussion of ideas for application concepts and functionalities were discussed. A deck of post-its and a marker where delivered to each participant, motivating discussing and creativity and helping to better visualize the ideas that were generated.

F.5   Conclusion

Two themes for a possible mobile solution were taken into account, those being, Ripening Control and Pests and Diseases Prevention and Control. Also, two distinct personas were presented: the smaller, less educated, older farmer and the medium/larger winegrower, that is more used to interact with ICTs and more knowledgeable. Attached to each persona, a problem scenario was also shown. Read a more detailed description on the scenarios and personas created in sections **??** and 4.2.1.2.

These are the ideas and conclusions that resulted from this activity:

- **Small winegrower** — For the smaller winegrower persona, which probably has never even used a smartphone, a good idea to work around the lack of interaction with complex ICTs would be to have an informal caregiver, for example a son or younger member of the family to bridge the gap between the technology and the farmer.

    - **Ripening Control** — Related to Ripening Control an interesting idea to come up in this activity was to provide a less complex mobile solution, for example, using an USSD protocol for the user to check the laboratory results.

    - **Pests and Diseases Prevention and Control** — due to the complexity of this theme it would be hard to provide functionalities besides presenting reference material using a messaging system.

- **Medium/Large winegrower** — This user profile allows for more complex functionalities and the integration with other technologies, and for higher interaction levels.

    - **Ripening Control** — Within this theme two distinct players are the laboratory technicians and the farmer. Some ideas presented were: for the laboratory were to: Send/-Make reports available, Optimize/computerise data input in the system, Automatic generation of reports with graphs and other visualization methods. For the farmer he would: Receive alerts and the reports and Visualize this data. A problem emerges,

this mobile solution would require a lower degree of interaction from the farmer and would be mostly used from the laboratory side. As the goal of this dissertation is to study farmer's interaction with a mobile solution this theme is not the most suitable.

– **Pests and Diseases Prevention and Control** — This theme also has two players: the expert side, that being an association or a cooperative, and the farmer. For the cooperative some functionalities would be: Keep records, Help with decision making, Send alerts/warning. The farmer would: Map plots, Contact experts (including sending photos/videos), Receive warnings and Receive instructions about treatment applications.

Concluding, the best opportunity for development would be a mobile application for Pests and Diseases Prevention and Control and the user profile that allows the creation of a more complex system would be the medium/large winegrower. Having said that, and as mentioned in 4.1.2, small farmers constitute the majority of producers in the Douro region, so it's also important to take this into consideration and create an application that fits both user profiles.
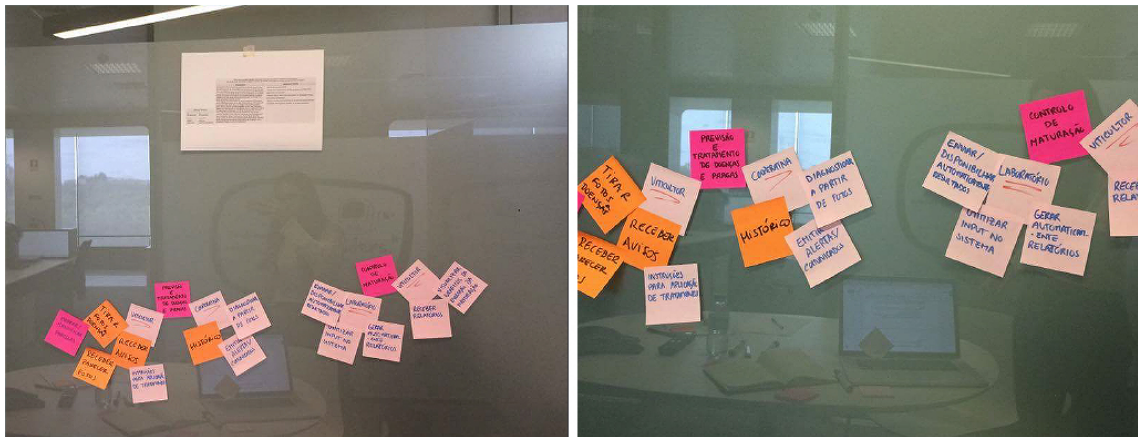
Figure F.1: Activity Setup

Brainstorming Activity

Appendix G

Personas and Scenarios

"Era caro e preferi perder algumas uvas do que estar a comprar os produtos.
Ao preço que nos estão a pagar o vinho, se perder uma pipa ou duas compensa não o tratar"

José Pereira

age
75 years old

education
primary school

role
Smallholder winegrower

mobile phone
doesn't own a mobile phone

SCENARIO

José learned everything he knows about his business from his father.

He wakes up at 6AM everyday, he lives with his daughter and his grandson in a rural region of Portugal. His grandson helps him check if there are any alerts or releases for the region, provided by the SNAA (Serviço Nacional de Avisos Agrícolas) online, and he does so on his personal laptop. If needed he prints the information for José to read later. After arriving to his 1 hectare of land José starts by checking if there is any breakage on the vines, any visible signs of fungus or any bugs. If José finds the need to apply any products/pesticides he usually does so with the help from family members on the weekend and usually applies it by instinct and doesn't follow the recommendations of the amount of treatment cycles due to the high costs.

GOALS & TASKS

- Lose the least amount of vines
- Track the maturation of the grapes to know the right time to harvest
- Know how to prevent and treat pests and diseases (what products to apply)
- Have the most profit possible

"Para competir com o mercado lá fora é preciso adotar as novas tecnologias, que permitem fazer coisas impensáveis há anos atrás. Quem não muda não evolui."

Alfredo Teixeira

age
55 years old

role
Winegrower

education
higher education

mobile phone
owns an android smartphone

SCENARIO	GOALS & TASKS
Alfredo is one of the biggest wine producers in the Douro region, he inherited the business of his father and worked his way up and now owns over 70 hectares of land. He deals with a lot of pressure on a daily basis, his main motivation is to get a better understanding of the state of production and achieve the best possible quality wine. That being he procedes to send samples of grapes from different plots to a lab. This control of maturity indicates the right time to begin harvesting each plot. After sending the samples to the lab, Alfredo waits for the results in his Email box or calls the lab if he has poor coverage. He first receives the results from the Summary Analysis, these are the most valued results, and then he receives the Supplementary Analysis. Also relating to the grape's quality José relies on the same association that does the lab tests to get advice and visits relating to pests and diseases diagnosis and treatment.	- Estimate production - Track the maturation of the grapes to know the right time to harvest - Detect signs that indicate pests or diseases (bugs, coloration of leaves) - Apply products/pesticides in localised applications - Achieve the highest quality of grape possible

Appendix H

High-Fidelity Prototype Interface

Screen 1 (Mapa - form)

12:30
::: Mapa

Nome da Parcela
Norte Forte

Tipo de Casta
Alcoa ▾

Sub-Região
Baixo Corgo ▾

Historial de ataque da traça ⊙

Screen 2 (Mapa - satellite)

12:30
::: Mapa ⌕ ⋮

Screen 3 (Mapa - Tipo de Vista)

12:30
::: Mapa ⌕ ⋮

Tipo de Vista:
Satélite
Terreno
Mapa de Temperatura

Screen 4 (Mapa - temperature)

12:30
::: Mapa ⌕ ⋮

Screen 5 (Mapa - Parcela)

12:30
✕ Mapa 🗑 ⋮

Parcela:
Norte Forte

Prevenção
Amostras   Armadilhas   Estimativa de Risco

Controlo
Tratamentos   Confusão Sexual   Monitorização

Início   Mapa   Especialista   Sensores   Referência

Screen 6 (Armadilhas list)

12:30
← Armadilhas ⌕ ⋮
Parcela: Norte Forte

Armadilha #1
Data da primeira contagem: 29/05

Armadilha #2
Data da primeira contagem: 29/05

Armadilha #3
Data da primeira contagem: 29/05

Screen 7 (Armadilhas - map)

12:30
← Armadilhas ⌕ ⋮

Nome da Armadilha

Screen 8 (Armadilhas - map with name)

12:30
← Armadilhas ⌕ ⋮

Nome da Armadilha
Armadilha #4

Screen 9 (Armadilhas - calendar)

12:30
← Armadilhas ⋮
Armadilha: #4

‹ Junho 2017 ›
S T Q Q S S D
            1 2
3 4 5 6 7 8 9
10 11 12 13 14 15 16
17 18 19 20 21 22 23
24 25 26 27 28 29 30

11 Junho   N° ADULTOS —

CONTAGEM MANUAL   CONTAGEM AUTOMÁTICA

Screen 10 (Armadilhas - photo)

12:30
← Armadilhas ⋮
Armadilha: #4

Screen 11 (Armadilhas - 120 adultos)

12:30
← Armadilhas ⋮
120 adultos
Contagem Manual

Screen 12 (Armadilhas - 120 adultos, count 3)

12:30
← Armadilhas ⋮
120 adultos
3

Início   Mapa   Especialista   Sensores   Referência

Screen 1:

Referência

Introdução ▾

A traça da uva, Lobesia botrana é considerada a principal praga das vinhas da Região Demarcada do Douro (RDD) pela importância económica dos prejuízos que origina, já que para além dos estragos directos provocados pelas lagartas, os estragos indirectos assumem particular relevo devido à instalação de podridões, em especial, da podridão cinzenta.

Início   Mapa   Especialista   Sensores   Referência

Screen 2:

Referência

Introdução ▾
Morfologia
Biologia
Estragos e Prejuízos
Estimativa de Risco
Meios de Proteção
Culturais
Tratamentos
Confusão Sexual
Inimigos Naturais

Início   Mapa   Especialista   Sensores   Referência

Screen 3:

Referência

Estimativa de Risco ▾

Em primeiro lugar a colocação na parcela de uma armadilha de atração sexual é imprescindível para indicar o momento no qual se devem concentrar as estimativas do risco de cada geração (indicam o início e o final do período de voo e portanto do período de postura).

A armadilha deve ser colocada numa parcela com historial de ataque, ao nível dos cachos.

Screen 4:

Procurar

Introdução ▾

A traça da uva, Lobesia botrana é considerada a principal praga das vinhas da Região Demarcada do Douro (RDD) pela importância económica dos prejuízos que origina, já que para além dos estragos directos provocados pelas lagartas, os estragos indirectos assumem particular relevo devido à instalação de podridões, em especial, da podridão cinzenta.

Início   Mapa   Especialista   Sensores   Referência

Screen 5:

armadilha   ‹   ›

Estimativa de Risco ▾

Em primeiro lugar a colocação na parcela de uma armadilha de atração sexual é imprescindível para indicar o momento no qual se devem concentrar as estimativas do risco de cada geração (indicam o início e o final do período de voo e portanto do período de postura).

A armadilha deve ser colocada numa parcela com historial de ataque, ao nível dos cachos.

Appendix I

Usability Testing Protocol

RESEARCH CENTER FOR ASSISTIVE INFORMATION AND COMMUNICATION SOLUTIONS

ISO/IEC 25062 Usability Test Protocol

2013

TABLE OF CONTENTS

1. Users

The number of participants required for this usability test is 5 to 10 people.
There will be two different profiles represented, small and medium/large winegrowers. The participants will be selected by a cooperative member and they'll will take into account two factors: the size of land of the farmer and also their technological proficiency. Technological proficiency is an important characteristic because of the big disparities present in the region when it comes to winegrowers interaction with different ICTs, particularly smartphones.

2. Context of product use in the test

2.1. Test facility

The test will be conducted in a room in the cooperative facilities. The setting of the test will have the participant seated in a chair to provide comfort and facilitate the test conduction. This differs from the normal context of use drastically, because the system is expected to be used in the field, which means the user will be using it standing up and possibly under extreme weather conditions, such as high temperatures or heavy rain.

2.2. Participant's computing environment

The test will be conducted in a smartphone, model Sony Xperia Z3 Compact running Android 4.4.4. (KitKat) operating system.

2.3.   Display devices

The screen of the device has the following characteristics: screen size of 4.6 inches and resolution of 720x128 pixels.

3.   Test procedure

3.1.   Tasks to be tested

The most important things that every user would be able to accomplish using this mobile app would be: Visualizing the moth's flight curve graph; Checking if new alerts were issued; Seeing what treatments are scheduled for the day and in the future; Mapping plots and performing selective prevention and control; Contacting an expert; Reading sensors outputs and Reading reference material. Therefore the following scenarios illustrate these goals.

The participants will be asked to perform the following tasks:

Task 1 - You've been counting adults and nests in order to know when and how to perform treatment. Change the data range of the moth's flight curve to the 16th of April to the 11th of June and see the number of captured adults and nests counted during the week of 23-29 April.
   - **Ideal Flow:** [Login > Grapevine Moth > Edit date (28th May to 16th of May) > Click on 23rd-29th of April]
   - **Successful completion:** reading 78 adults and 120 nests

Task 2 – In order to stay updated on the latest pests and diseases attacking the Douro Region you want to open the latest alert sent out by DRAP
   - **Ideal Flow:** [Click on button with label "Circular nº 13" on "Avisos Agrícolas" Card]
   - **Successful completion:** opening the pdf alert of "Circular nº 13"

Task 3 – It's important to perform treatments on time so you want to see your scheduled treatments for the 10 and 11th of June and tell me which one has more urgency
   - **Ideal Flow:** [Scroll to bottom of "Página Inicial" screen > Swipe left over dates on "Tratamentos" Card or Click on righ arrow]
   - **Successful completion:** Indicating "Tratamento Salero" as the most urgent one

Task 4 **– You want to perform treatment selectively and to do so you need to (1) create and map a new plot . Now you want to (2) change the view to a heat map in order to see what areas of the plot are more prone to being attacked by the grapevine moth. Now on that same plot (3) add a trap and perform the first count of adult moths in that trap.**

- **Ideal Flow: Breaking it down in sub tasks**

  - **(1) [Click on "Mapa" in the bottom navigation > Click on plus floating action button > Simulate click on screen to map points > Click on check floation action button > Simulate field inputs > Click next > Simulate field inputs > Click on save floating action button]**

  - **(2) [Click on layers icon > Select on menu "Mapa de Temperatura"]**

  - **(3) [Click on plot > Click on "Armadilhas" in "Prevenção" card > Click plus fab > Simulate click on map to pin trap location > Select day in date picker > Click Automatic Count > Simulate photo capture of trap > Click next > Input grey area manual count > Click Save]**

- **Successful completion: (1) Mapping plot, (2) Visualizing heat map and (3) Adding a trap and performing automatic count**

Task 5 **- Contact expert Eng. Sandra by chat and send her three images from sample called "Amostra #12" with a question attached**

- **Ideal Flow: [Click on "Especialista" in the bottom navigation > Click Chat button > Select "Eng. Sandra" from experts available > Select sample > Select three images > Add Image annex > Add text description > Send message]**

- **Successful completion: Sending images with description to Eng. Sandra**

Task 6 **- Read air humidity from the sensor in the weather station "Estação 2"**

- **Ideal Flow: [Click on "Sensores" in the bottom navigation > Select weather station "Estação 2"]**

- **Successful completion: Reading percentage of 10%**

Task 7 **- Open reference information about how to apply traps**

- **Ideal Flow: [Click on "Referência" in the bottom navigation > Search "armadilha" and go through search results OR Click on dropdown and go to "Estimativa de Risco"]**

- **Successful completion: Indicating paragraph that mentions how to place a trap**

3.2. Participant general instructions

The participants will be asked to sign a consent for recording their usability test. Instructions will be given about the level of interaction of the prototype: not allowing data input and not allowing full free navigation, therefore tasks need to be performed in order.

Participants can interact with the facilitator when they encounter a system failure and ask for assistance. Two types of assistance will be give, first a less direct assistance and a more direct and intrusive assistance (e.g. clicking on the screen for them) only as a last resort.

4. Performance and satisfaction metrics

4.1. Criteria and measurements

With these tests different factors will be measured, firstly if the users feel comfortable and not confused navigating through the prototype, if the main tasks they would be interested in being able to perform are included in the prototype. Different levels of interaction and components will be tested, to see which work best.

4.2. Metrics for effectiveness, efficiency and satisfaction

The metrics to be measured and reported:

- Effectiveness: task completion and frequency of errors (critical and non-critical) and efficiency: time on task

- A SUS questionnaire to measure satisfaction

5. References

National Institute of Standards and Technology, *NISTIR 7432 – Common Industry Specification for Usability – Requirements*, 2007

I.1 SUS

Portuguese translation

Usando a escala abaixo, por favor coloque um círculo no número mais próximo da palavra que mais se aproxima aos seus sentimentos acerca do produto/website.

1. Penso que gostaria de usar este sistema frequentemente

Discordo fortemente	1	2	3	4	5	Concordo fortemente

2. Achei o sistema desnecessariamente complexo

Discordo fortemente	1	2	3	4	5	Concordo fortemente

3. Achei o sistema fácil de usar

Discordo fortemente	1	2	3	4	5	Concordo fortemente

4. Penso que precisaria do apoio técnico para conseguir usar o sistema

Discordo fortemente	1	2	3	4	5	Concordo fortemente

5. Achei que as várias funções do sistema estavam bem integradas

Discordo fortemente	1	2	3	4	5	Concordo fortemente

6. Achei que havia demasiadas inconsistências neste sistema

Discordo fortemente	1	2	3	4	5	Concordo fortemente

7. Imagino que a maioria das pessoas consegue aprender a usar este sistema muito rapidamente

Discordo fortemente	1	2	3	4	5	Concordo fortemente

8. Achei o sistema muito incómodo de usar

Discordo fortemente	1	2	3	4	5	Concordo fortemente

9. Senti-me muito confiante ao usar o sistema

Discordo fortemente	1	2	3	4	5	Concordo fortemente

10. Precisei de aprender muitas coisas antes de conseguir começar a usar o sistema

Discordo fortemente	1	2	3	4	5	Concordo fortemente

Appendix J

Usability Test Extensive Results

U01

TASK	TOT	TOT (SECONDS)	ERRORS	ASSISTS (LIGHT)	ASSISTS (HEAVY)
Task 1.1	4.10	250	9	6	2
Task 1.2	0.27	27	1	1	-
Task 2	0.17	17	-	1	-
Task 3	1.17	77	2	2	-
Task 4.1	2.37	157	2	1	1
Task 4.2	0.52	52	3	2	1
Task 4.3.1	1.24	84	2	3	1
Task 4.3.2	1.34	94	2	2	-
Task 5	3.50	230	3	4	1
Task 6	1.39	99	1	2	-
Task 7	0.55	55	1	2	1

U02

TASK	TOT	TOT (SECONDS)	ERRORS	ASSISTS (LIGHT)	ASSISTS (HEAVY)
Task 1.1	2.25	145	3	3	-
Task 1.2	0.04	4	-	-	-
Task 2	0.12	12	1	-	-
Task 3	1.20	80	1	2	2
Task 4.1	2.05	125	2	2	1
Task 4.2	0.27	27	-	1	1
Task 4.3.1	1.48	108	2	1	1
Task 4.3.2	0.53	53	1	1	-
Task 5	0.40	40	2	2	-
Task 6	0.12	12	-	-	-
Task 7	1.08	68	-	-	1

U04

TASK	TOT	TOT (SECONDS)	ERRORS	ASSISTS (LIGHT)	ASSISTS (HEAVY)
Task 1.1	0.16	16	-	-	-
Task 1.2	0.06	6	-	-	-
Task 2	0.02	2	-	-	-
Task 3	1.04	64	2	1	1
Task 4.1	0.35	35	-	1	-
Task 4.2	0.13	13	-	-	-
Task 4.3.1	0.20	20	-	-	-
Task 4.3.2	0.34	34	-	-	-
Task 5	0.29	29	-	-	-
Task 6	0.13	13	-	-	-
Task 7	1.11	71	-	-	1

U03

TASK	TOT	TOT (SECONDS)	ERRORS	ASSISTS (LIGHT)	ASSISTS (HEAVY)
Task 1.1	0.06	6	-	-	-
Task 1.2	0.07	7	-	-	-
Task 2	0.04	4	-	-	-
Task 3	0.15	15	-	-	-
Task 4.1	0.09	9	-	-	-
Task 4.2	0.11	11	1	-	-
Task 4.3.1	0.12	12	-	-	-
Task 4.3.2	0.17	17	-	-	-
Task 5	0.19	19	1	-	-
Task 6	0.06	6	-	-	-
Task 7	0.35	35	-	1	-

U05

TASK	TOT	TOT (SECONDS)	ERRORS	ASSISTS (LIGHT)	ASSISTS (HEAVY)
Task 1.1	0.44	44	-	1	-
Task 1.2	0.10	10	-	-	-
Task 2	0.02	2	-	-	-
Task 3	1.41	101	2	3	1
Task 4.1	0.57	57	1	-	-
Task 4.2	0.26	26	3	-	-
Task 4.3.1	0.57	57	3	-	1
Task 4.3.2	0.52	52	-	-	-
Task 5	1.37	97	2	1	-
Task 6	0.07	7	-	-	-
Task 7	0.13	13	-	-	-

U06

TASK	TOT	TOT (SECONDS)	ERRORS	ASSISTS (LIGHT)	ASSISTS (HEAVY)
Task 1.1	0.28	28	-	-	-
Task 1.2	0.20	20	-	-	-
Task 2	0.53	53	-	1	-
Task 3	0.42	42	-	-	-
Task 4.1	1.36	96	-	2	1
Task 4.2	0.14	14	-	-	-
Task 4.3.1	0.33	33	-	-	1
Task 4.3.2	0.16	16	-	-	-
Task 5	1.11	71	-	1	-
Task 6	0.17	17	-	-	-
Task 7	1.19	79	-	1	1

TASK 1.1

USER #	TIME ON TASK [SECONDS]	UNASSISTED TASK EFFECTIVENESS [(%)COMPLETE]	LIGHTLY ASSISTED TASK EFFECTIVENESS [(%)COMPLETE]	HEAVILY ASSISTED TASK EFFECTIVENESS [(%)COMPLETE]	ERRORS	ASSISTS (LIGHT)	ASSISTS (HEAVY)
U01	250	0%	0%	100%	9	6	2
U02	145	0%	100%	100%	3	3	0
U03	6	100%	100%	100%	0	0	0
U04	16	100%	100%	100%	0	0	0
U05	44	0%	100%	100%	0	1	0
U06	28	100%	100%	100%	0	0	0
Mean	81,5	50%	90%	100%	2	1,67	0,34
Standard Deviation	97	60%	50%	0%	3,7	2,5	0,9
Min	6	0%	0%	100%	0	0	0
Max	250	100%	100%	100%	9	6	2

TASK 1.2

USER #	TIME ON TASK [SECONDS]	UNASSISTED TASK EFFECTIVENESS [(%)COMPLETE]	LIGHTLY ASSISTED TASK EFFECTIVENESS [(%)COMPLETE]	HEAVILY ASSISTED TASK EFFECTIVENESS [(%)COMPLETE]	ERRORS	ASSISTS (LIGHT)	ASSISTS (HEAVY)
U01	27	0%	100%	100%	1	1	0
U02	4	100%	100%	100%	0	0	0
U03	7	100%	100%	100%	0	0	0
U04	6	100%	100%	100%	0	0	0
U05	10	100%	100%	100%	0	0	0
U06	20	100%	100%	100%	0	0	0
Mean	13	90%	100%	100%	0,17	0,17	0
Standard Deviation	10	50%	0%	0%	0,5	0,5	0
Min	4	0%	100%	100%	0	0	0
Max	27	100%	100%	100%	1	1	0

TASK 2

USER #	TIME ON TASK [SECONDS]	UNASSISTED TASK EFFECTIVENESS [(%)COMPLETE]	LIGHTLY ASSISTED TASK EFFECTIVENESS [(%)COMPLETE]	HEAVILY ASSISTED TASK EFFECTIVENESS [(%)COMPLETE]	ERRORS	ASSISTS (LIGHT)	ASSISTS (HEAVY)
U01	17	0%	100%	100%	0	1	0
U02	12	100%	100%	100%	0	0	0
U03	4	100%	100%	100%	0	0	0
U04	2	100%	100%	100%	0	0	0
U05	2	100%	100%	100%	0	0	0
U06	53	100%	100%	100%	0	1	0
Mean	15	90%	100%	100%	0	0,34	0
Standard Deviation	20	50%	0%	0%	0	0,52	0
Min	2	0%	100%	100%	0	0	0
Max	53	100%	100%	100%	0	1	0

TASK 3

USER #	TIME ON TASK [SECONDS]	UNASSISTED TASK EFFECTIVENESS [(%)COMPLETE]	LIGHTLY ASSISTED TASK EFFECTIVENESS [(%)COMPLETE]	HEAVILY ASSISTED TASK EFFECTIVENESS [(%)COMPLETE]	ERRORS	ASSISTS (LIGHT)	ASSISTS (HEAVY)
U01	77	0%	100%	100%	2	2	0
U02	80	0%	0%	100%	1	2	2
U03	15	100%	100%	100%	0	0	0
U04	64	0%	0%	100%	2	1	1
U05	101	0%	0%	100%	2	3	1
U06	42	100%	100%	100%	0	1	0
Mean	64	40%	50%	100%	1,17	1,5	0,67
Standard Deviation	31	60%	60%	0%	0,99	1,05	0,82
Min	15	0%	0%	100%	0	0	0
Max	101	100%	100%	100%	2	3	2

TASK 4.1

USER #	TIME ON TASK [SECONDS]	UNASSISTED TASK EFFECTIVENESS [(%)COMPLETE]	LIGHTLY ASSISTED TASK EFFECTIVENESS [(%)COMPLETE]	HEAVILY ASSISTED TASK EFFECTIVENESS [(%)COMPLETE]	ERRORS	ASSISTS (LIGHT)	ASSISTS (HEAVY)
U01	157	0%	0%	100%	2	1	1
U02	125	0%	0%	100%	2	2	1
U03	9	100%	100%	100%	0	0	0
U04	35	0%	100%	100%	0	1	0
U05	57	100%	100%	100%	1	0	0
U06	96	0%	0%	100%	0	2	1
Mean	80	40%	50%	100%	0,84	1	0,5
Standard Deviation	57	60%	60%	0%	0,99	0,9	0,55
Min	9	0%	0%	100%	0	0	0
Max	157	100%	100%	100%	2	2	1

TASK 4.2

USER #	TIME ON TASK [SECONDS]	UNASSISTED TASK EFFECTIVENESS [(%)COMPLETE]	LIGHTLY ASSISTED TASK EFFECTIVENESS [(%)COMPLETE]	HEAVILY ASSISTED TASK EFFECTIVENESS [(%)COMPLETE]	ERRORS	ASSISTS (LIGHT)	ASSISTS (HEAVY)
U01	52	0%	0%	100%	3	2	1
U02	27	0%	0%	100%	0	1	1
U03	11	100%	100%	100%	1	0	0
U04	13	100%	100%	100%	0	0	0
U05	26	100%	100%	100%	3	0	0
U06	14	100%	100%	100%	0	0	0
Mean	24	70%	70%	100%	1,17	0,5	0,34
Standard Deviation	16	60%	60%	0%	1,48	0,84	0,52
Min	11	0%	0%	100%	0	0	0
Max	52	100%	100%	100%	3	2	1

TASK 4.3.1

USER #	TIME ON TASK [SECONDS]	UNASSISTED TASK EFFECTIVENESS [(%)COMPLETE]	LIGHTLY ASSISTED TASK EFFECTIVENESS [(%)COMPLETE]	HEAVILY ASSISTED TASK EFFECTIVENESS [(%)COMPLETE]	ERRORS	ASSISTS (LIGHT)	ASSISTS (HEAVY)
U01	84	0%	0%	100%	2	3	1
U02	108	0%	0%	100%	2	1	1
U03	12	100%	100%	100%	0	0	0
U04	20	100%	100%	100%	0	0	0
U05	57	0%	0%	100%	3	0	1
U06	33	0%	0%	100%	0	0	1
Mean	53	40%	40%	100%	1,17	0,67	0,67
Standard Deviation	38	60%	60%	0%	1,33	1,22	0,52
Min	12	0%	0%	100%	0	0	0
Max	108	100%	100%	100%	3	3	1

TASK 4.3.2

USER #	TIME ON TASK [SECONDS]	UNASSISTED TASK EFFECTIVENESS [(%)COMPLETE]	LIGHTLY ASSISTED TASK EFFECTIVENESS [(%)COMPLETE]	HEAVILY ASSISTED TASK EFFECTIVENESS [(%)COMPLETE]	ERRORS	ASSISTS (LIGHT)	ASSISTS (HEAVY)
U01	94	0%	100%	100%	2	2	0
U02	53	0%	100%	100%	1	1	0
U03	17	100%	100%	100%	0	0	0
U04	34	100%	100%	100%	0	0	0
U05	52	100%	100%	100%	0	0	0
U06	16	100%	100%	100%	0	0	0
Mean	45	70%	100%	100%	0,5	0,5	0
Standard Deviation	30	60%	0%	0%	0,84	0,84	0
Min	16	0%	100%	100%	0	0	0
Max	94	100%	100%	100%	2	2	0

TASK 5

USER #	TIME ON TASK [SECONDS]	UNASSISTED TASK EFFECTIVENESS [(%)COMPLETE]	LIGHTLY ASSISTED TASK EFFECTIVENESS [(%)COMPLETE]	HEAVILY ASSISTED TASK EFFECTIVENESS [(%)COMPLETE]	ERRORS	ASSISTS (LIGHT)	ASSISTS (HEAVY)
U01	230	0%	0%	100%	3	4	1
U02	40	0%	100%	100%	2	2	0
U03	19	100%	100%	100%	1	0	0
U04	29	100%	100%	100%	0	0	0
U05	97	0%	100%	100%	2	1	0
U06	71	0%	100%	100%	0	1	0
Mean	81	40%	90%	100%	1,34	1,34	0,17
Standard Deviation	79	60%	50%	0%	1,22	1,51	0,41
Min	19	0%	0%	100%	0	0	0
Max	230	100%	100%	100%	3	4	1

TASK 6

USER #	TIME ON TASK [SECONDS]	UNASSISTED TASK EFFECTIVENESS [(%)COMPLETE]	LIGHTLY ASSISTED TASK EFFECTIVENESS [(%)COMPLETE]	HEAVILY ASSISTED TASK EFFECTIVENESS [(%)COMPLETE]	ERRORS	ASSISTS (LIGHT)	ASSISTS (HEAVY)
U01	99	0%	100%	100%	1	2	0
U02	12	100%	100%	100%	0	0	0
U03	6	100%	100%	100%	0	0	0
U04	13	100%	100%	100%	0	0	0
U05	7	100%	100%	100%	0	0	0
U06	17	100%	100%	100%	0	0	0
Mean	26	90%	100%	100%	0,17	0,34	0
Standard Deviation	37	50%	0%	0%	0,41	0,82	0
Min	6	0%	100%	100%	0	0	0
Max	99	100%	100%	100%	1	2	0

TASK 7

USER #	TIME ON TASK [SECONDS]	UNASSISTED TASK EFFECTIVENESS [(%)COMPLETE]	LIGHTLY ASSISTED TASK EFFECTIVENESS [(%)COMPLETE]	HEAVILY ASSISTED TASK EFFECTIVENESS [(%)COMPLETE]	ERRORS	ASSISTS (LIGHT)	ASSISTS (HEAVY)
U01	55	0%	0%	100%	1	2	1
U02	68	0%	0%	100%	0	0	1
U03	35	0%	100%	100%	0	1	0
U04	71	100%	100%	100%	0	0	0
U05	13	100%	100%	100%	0	0	0
U06	79	0%	0%	100%	0	1	1
Mean	54	40%	50%	100%	0,17	0,67	0,5
Standard Deviation	26	60%	60%	0%	0,41	0,82	0,55
Min	13	0%	0%	100%	0	0	0
Max	79	100%	100%	100%	1	2	1