TÉCNICO LISBOA

MIMBCD-UI

Medical Imaging Multimodality Breast Cancer Diagnosis User Interface

Francisco Maria Calisto

Master Project Report to obtain the Master of Science Degree in

Computer Science and Engineering

Advisor: Prof. Dr. Jacinto Nascimento

Co-Advisor: Prof. Dr. Daniel Gonçalves

October 2017

Abstract

Breast cancer is one of the most commonly occurring type of cancer among women [1], the main strategy to reduce morbidity and also mortality being early detection and treatment based on medical imaging technologies. The current workflow applied in breast cancer diagnosis involves several imaging multi-modalities. A need for multi-modal imaging in breast cancer diagnosis is based on the fact that no single modality has the specificity and the sensitivity high enough for reliable diagnosis [2]. Nevertheless, their combination can significantly increase diagnostic accuracy [3, 4, 5, 6], this also reduces the number of unnecessary biopsies, which leads to better patient care and lower health care costs.

It is becoming increasingly apparent in medical image analysis that multiple imaging multi-modalities are required for the accurate treatment and diagnosis of the disease. An example to this, a patient will initially undertake a Mammogram (MG) for breast cancer diagnosis, with abnormal cases being further investigated using a combination of tomo-synthesis, in our case of study, Ultrasound (US) and Magnetic Resonance Imaging (MRI). This images then guide the physicians final diagnosis of suspicious lesions in order to achieve acceptable levels of specificity.

Our work is to develop techniques that enable the development of an improved user interface breast cancer diagnosis multimodality of image system based on any combination of MG, US, MRI and Text Data. The plan involves the development and design of an user interface for automatic detection, segmentation and classification from breast MG, US and MRI, as well as, textual data notations and information visualisation.

Keywords: medical, imaging, multimodality, breast cancer, diagnosis, user interface

Resumo

O cancro da mama é um dos tipos de cancro que mais commumente ocorrem entre as mulheres [1], a principal estratégia para reduzir a mortalidade sendo a sua detecção precoce e tratamento baseado em tecnologias de imagens médicas. O fluxo de trabalho corrente aplicado no diagnóstico do cancro de mama envolve várias opções de imagens multi-modais. A necessidade de imagem multi-modal no diagnóstico do cancro de mama é baseado no facto de que nenhuma modalidade tem a especificidade e a sensibilidade alta o suficiente para o diagnóstico confiável [2]. No entanto, a sua combinação pode aumentar significativamente a precisão do diagnóstico [3, 4, 5, 6], isto também reduz o número de biópsias desnecessárias, o que leva a uma melhor assistncia ao paciente e reduzir os custos de cuidados de saúde.

É cada vez mais evidente a análise de imagens médicas em multi-modalidades de imagem visto serem necessárias para o tratamento preciso e diagnóstico da doença. Exemplo disso, é o caso de um paciente vai inicialmente realizar uma Mamografia (MG) para o diagnóstico do cancro da mama, com casos anormais sendo investigado usando uma combinação de tomo-síntese, no nosso caso de estudo, Ultrasom (US) e Resonancia Magnetica (MRI). Estas imagens, em seguida, orientar os médicos diagnóstico final de lesões suspeitas para atingir níveis aceitáveis de especificidade.

O nosso trabalho é desenvolver técnicas que permitam o desenvolvimento de uma interface de utilizador melhorada diagnóstico de cancro da mama multi-modalidade do sistema de imagem com base em qualquer combinação de MG, US, MRI e dados de texto. O plano envolve o desenvolvimento e concepção de uma interface de utilizador para detecção automática, segmentação e classificação de mama MG, US e MRI, bem como, as notações de dados textuais e visualização da informação.

Palavras-Chave: clinico, imagens, multi-modalidade, cancro da mama, diagnóstico, interface utilizador

Acronyms

CAD Computer-Aided Diagnosis. 4

MG Mamografia. v

MG Mammogram. iii, 5–7

MRI Resonancia Magnetica. v

MRI Magnetic Resonance Imaging. iii, 3, 5–7, 12

UI User Interface. 16

US Ultrasom. v

US Ultrasound. iii, 5–7

Chapter 1

Introduction

The Medical Imaging Multimodality Breast Cancer Diagnosis is a topic of great interest, it has been the subject of intensive research in the world of medicine. However the developments in terms of innovation in the computational world are still scarce. The Interface herein proposer deals with the processing and analysis of images. Indeed, this topic has a wide spectrum of applications raging from video surveillance based systems to medical applications.

In the proposed work, i.e., the analysis mammography using multi-modality images, several issues must be considered. First each image modality has its own image features. Which must be included in the interface. Second, for each image modality several and distinct image feature must be considered.

Masses and calcifications can be accurately diagnosed from cytological features [7] of the cells that constitute them. However, the diagnostic accuracy depends on the training, experience, and many indefinite factors of interpretation of the medical expert in cytological evaluation.

There were, in fact, some developments in the past facing the Computer-Based classification system [8, 9] that assists in the diagnosis of breast cells based on visual assessment of characteristics of the cells. A set of cytologic features [10], previously evaluated visually, are now replaced by digital ones, evaluated by image analysis. In this project, the interface will be used by several experts in the field, to collect the ground truth, for Mammograms, MRI and Ultrasounds images. Those mammography experts annotations will be a crucial step towards the performance evaluation of Machine Learning (ML) Based-Algorithms.

Doctors are accountable for decisions they make on behalf of their patients. Likewise, computer interface developers and engineers must assume accountability for limitations, assumptions and other unplanned deficiencies that impact on the integrity, validity, quantity and timeliness of data made accessible through their interfaces.

Art and science [11] applied to the user interface filed of clinical care are based on an unusual combination of non-judgement trust and exasperating mistrust [12]. Two major obstacles to good clinicians-patient communication are differences of language and culture [13]. Doctors and clinicians require that theirs patients keep no secrets or else an opportunity to reach the right diagnosis or select the proper therapy may be lost. At the same time, doctors and clinicians are taught to question everything they hear from both colleagues and patients. It is deeply ingrained in medical training to make no important decisions based on information supplied solely by others. The highly trained mistrust explains why many times patients complained that a dozen different people asked the same question. A deeply ingrained aversion to secrets and lies greatly characterise a clinicians attitude toward a computer interface where the responsibility of interface developers address and incorporate the concept of visual accountability extending well beyond medical user interfaces.

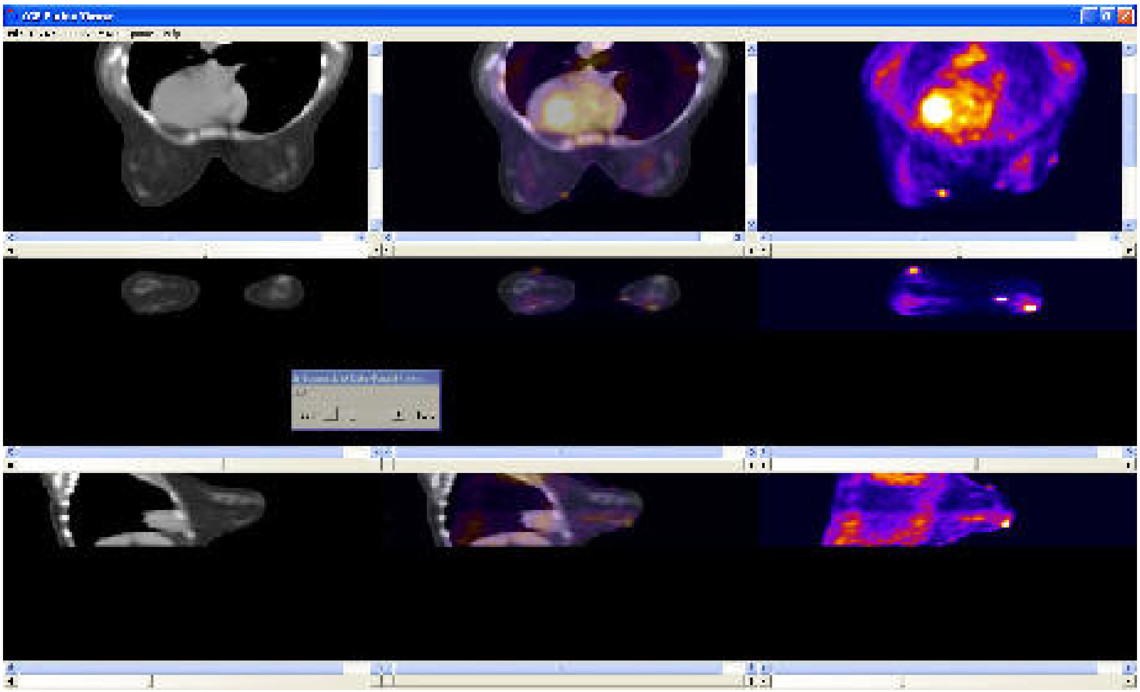

Figure 1.1: A screenshot of a fused data set.

The growing interest in multimodal interface development is inspired in large part by goals of supporting more flexible, transparent, efficient and powerfully expressive means of human-computer interaction than in the past. Multimodal interfaces are expected to support a wider range of diverse applications, be usable by a broader spectrum of the average population, and function more reliably under realistic and challenging usage conditions.

Computer-aided diagnosis often implies processing large and high dimensional datasets, for instance, high-resolution volumes containing millions of voxels.

Visualisation and analysis of such data can be very time demanding for physicians but also very computationally expensive for machines assisting diagnosis tasks. Fortunately, in many cases the relevant information for an application can be represented in lower dimensional spaces. If appropriately chosen and designed, dimensionality reduction methods will not only decrease the processing time but also facilitate any posterior analysis. Therefore, they can be of great use to a variety of Computer-Aided Diagnosis (CAD) applications, ranging from general problems such as classification and visualisation, to more specific ones like multi-modal registration or motion compensation.

Dimensionality reduction in CAD has relied mainly on linear methods and linear methods are however not suitable for handling non-linear complex relationships among the data samples. Non-linear approaches based on manifold learning are a good alternative for dimensionality reduction in such cases.

Medical Imaging Multimodality Breast Cancer Diagnosis User Interface (MIMBCD-UI) registration consists in finding a map between images of the same scene acquired with different imaging modalities. The standard approach to multi-modal registration is to use sophisticated similarity metrics such as mutual information to compare the images.

Chapter 2

Overview

CAD Based-Systems are typically single-user oriented that is, designed to support individual tasks such as notations and information visualisation. This personal and task-oriented approach for clinical software provides little support for the aggregation of resources and tools required in carrying out higher level activities for multimodality of medical imaging. It is left to the user to aggregate such resources and tools in meaningful bundles according to the activity at hand, and users often have to reconfigure this aggregation manually when shifting between a set of parallel activities and machines.

A suited number of studies have shown that clinical professionals, upon the act of organising and thinking in their work routines, which often carried out search of general objectives, often in collaboration with others [14, 15, 16], are significant mental and manual overhead associated with handling of parallel work and interruptions [17, 18]. The rest of the user interfaces in the current operating systems, fail to provide adequate support in the resumption of the previous activities and for an easy switching between parallel activities [19, 20].

Clinical user interfaces have been extensively discussed in the literature on information visualisation. MIMBCD-UI shows the details of an user interface for diagnosing breast cancer using multimodality medical imaging.

MIMBCD-UI have several benefits. In fact, the diagnosis it self is more efficient since the clinical users may navigate using the overview of multimodality of imaging rather than the others techniques. The overview of multimodality of imaging window aids users in keeping track of their current position in the information space [21]. Moreover the overview window itself give users task-relevant information and a feeling of control [22].

A multimodality of views permits to acquire better, more efficient and flexible information and to easily diagnose in it; however, it is more difficult to users to manage information in a more complex user interface.

Specifically, this project deals with the use of a recently proposed technique in literature: Deep Convolutional Neural Networks (CNNs).

These deep networks will incorporate information from several different modes: MRI, US images, MG images (both views CC and MLO) and text.

The proposed algorithm, called for multimodality CNNs (MMCNNs) will have the ability to process multimodal information at an unified and sustained manner.

This methodology needs to ”learn” what are the masses and calcifications.

So that is necessary to collect the ground truth, or notes of the masses and calcifications provided by medical experts.

For the collection of these notes, the design and development of an interface is necessary allows the user (in this case, the medical specialist) to display various types of image (i.e., US, MRI and MG), and that also allows for user interaction, particularly in providing the notes of the masses and calcifications.

For these reasons, it is crucial for the development of this project, cooperation with experts providing the above notes.

Chapter 3

Goals

Our primary goal id the development of the user interface for diagnosis of breast cancer in medical imaging multimodality that enable an improved breast cancer diagnosis system based.

It is intended to develop an user interface for monitoring and diagnosis of breast lesions in various medical imaging modalities. Imaging modalities to include in the work are:

- MG (including the views caudal-skull and oblique);
- US;
- MRI volumes;

With protocol already signed with the Fernando Fonseca Hospital, it is intended that this interface has two features:

(i) - Build a database with annotations in multimodality mammography image.

Provide the user (doctor) facility to draw / write down masses and calcifications, as well as the corresponding BI-RADS for each imaging modality. This annotation process can be built during the examination, and thus it is possible to build a database of medical notes.

(ii) - Follow-up of the patient. With this feature is to allow the doctor automate a multimodality inspection for the patient.

Based on the patient's identification (eg, via a query on the ID), and for a given type of mammography imaging, the system must return all images of this patient over a period of time (eg. Two or more years) entered by the doctor, and show these images (pre-recorded). This feature is critical for diagnosis because it allows, through information visualisation, observing not only the calcifications density and the morphological evolution of the masses in that time period.

Chapter 4

User Interface Contextualisation

The first step in successfully analysing the digital image is to specify the exact location of each masses nucleus or calcifications nucleus. The image is projected onto a computer screen, and the clinical medical operator uses, preferentially, a mouse button that will trace a rough outline of each visible masses (Figure 4.1) nucleus. On the other hand, the clinical medical operator will mark with dots the calcification (Figure 4.2) nucleus of cells.

For a precise and rigorous diagnosis of the cancer in mammography, it is necessary a successful step when analysing the image, specifying the exact location and morphology of the masses as well as calcifications.

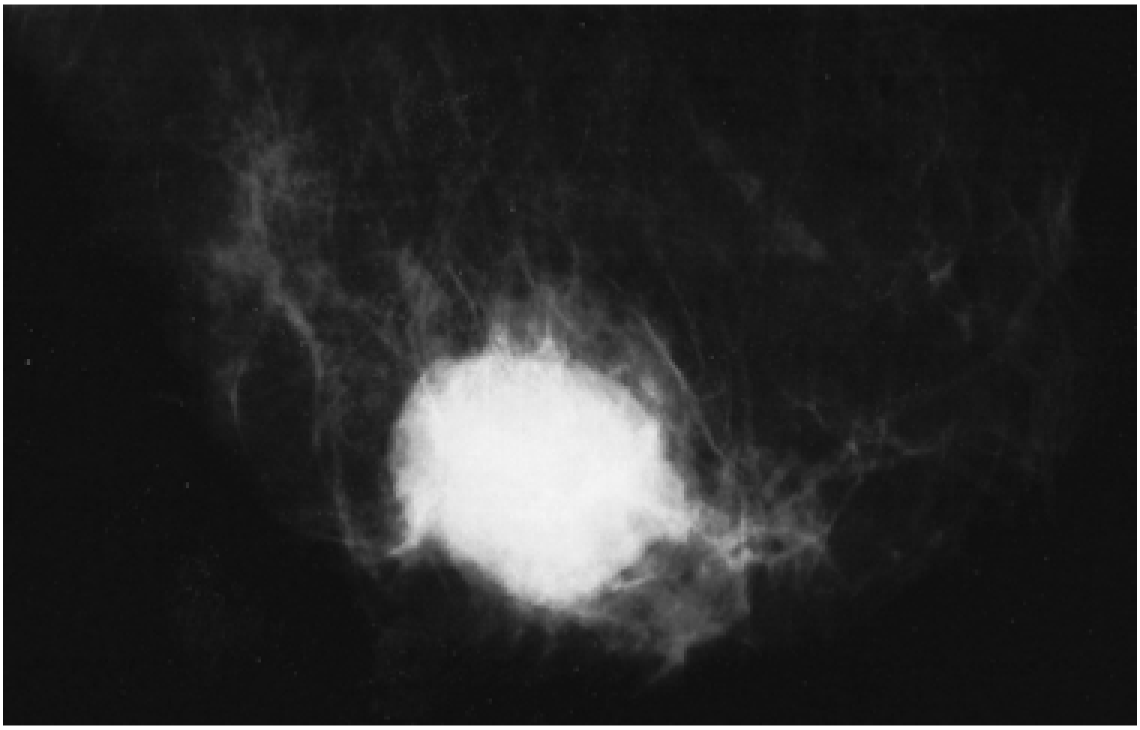

Figure 4.1: Mammographic image of a high-density mass

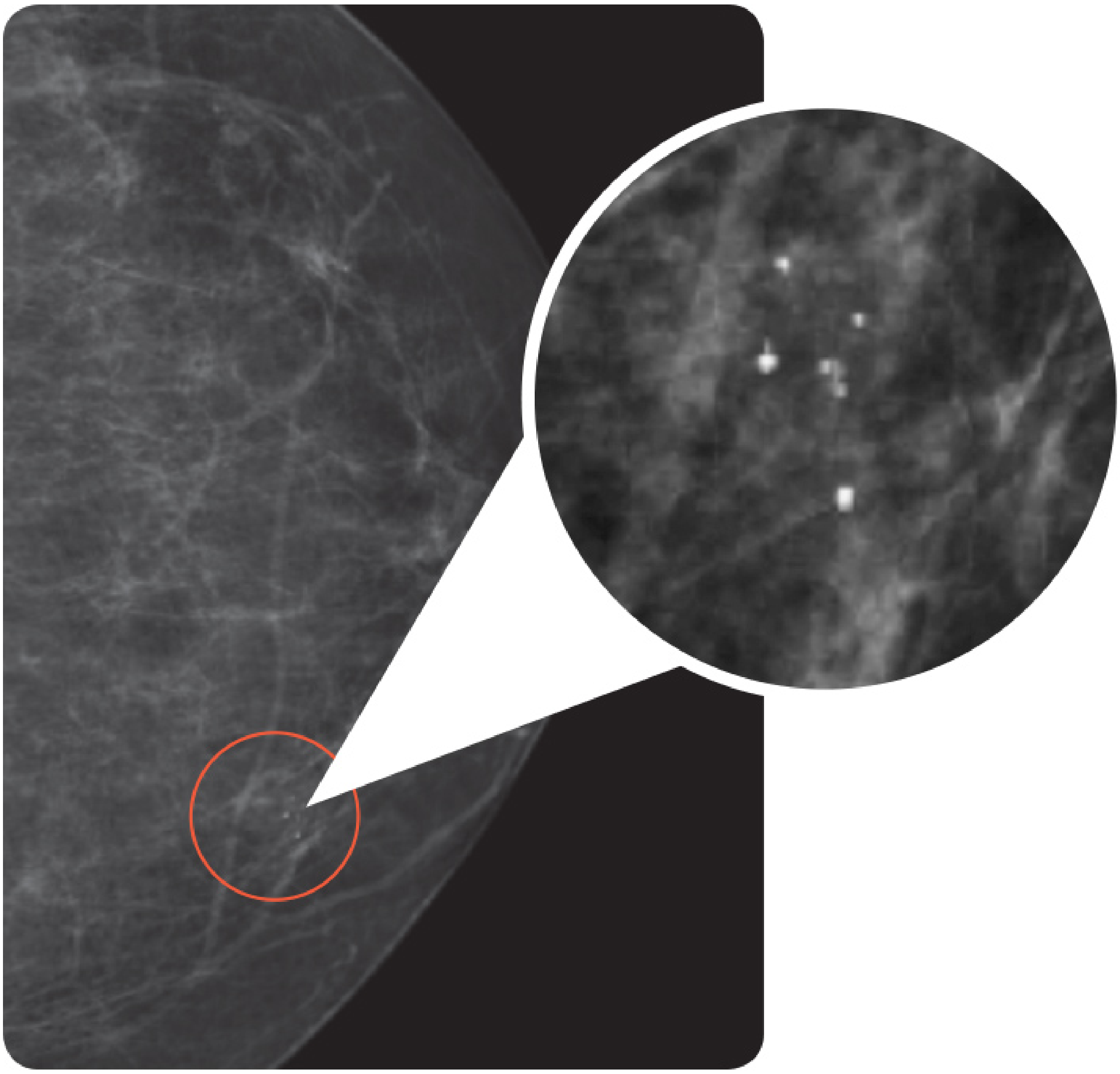

Figure 4.2: Mammogram shows calcifications, an early sign of breast cancer

Chapter 5

Related Work

Some systems have been designed to provide more direct support for managing multiple concurrent activities associated with a large amount of digital material and tools.

In the further section, we discuss software for both clinical and non-clinical imaging tools. More specifically, we address image modality concerning medical applications as well as non-medical applications (e.g., surveillance).

Also, we address software concerning the (non)-multimodality views and existing work in the field of medical and clinical user interfaces.

5.1 Activity-Based Computing

In this section we address other approaches like an Activity-Based Computing (ABC) for Medical Work in Hospitals [23] that presents the concept, which seeks to create computational support for human activities contributing to the growing research on support for human activities, mobility, collaboration, and context-aware computing. To summarise, activity-based computing builds and expands upon prior work within each of the areas described as activity management, virtual window management, collaboration support systems and context-awareness. However the last topics, it does not approach a multimodal view of images, but it was great on other fields of understanding the context and most of the problem/solutions.

5.2 Fine Needle Aspirate

Another direction of work is known as Fine Needle Aspirate (FNA) [24]. Basically, their class of approaches, by using computer based image analysing, we research a Breast Cytology Diagnosis via Digital Image Analysis [7] paper work that brings us an improvement on the diagnostic accuracy of breast FNA goal where an interactive computer system has been developed for evaluating cytologic features derived directly from a digital scan of breast FNA slides. The system uses computer vision technology techniques to analyse cell nuclei and classifies them using an inductive method based on linear programming.

The researched accuracy for medical imaging breast cancer diagnosis from FNAs varies considerably. Reported accuracy for visually diagnosing breast cancer from FNAs varies considerably. Giard and Hermans [**?**] researched on FNA performance parameters and found some sensitivities. The FNA diagnosis is highly operator-dependent and emphasised the need for developing individual performance characteristics for those doing this test. One goal of the present work is to improve the diagnostic accuracy of FNA by increasing its objectivity and thereby making it less operator-dependant. This image analysis and machine learning applied to breast cancer diagnosis and prognosis [23] study introduce us to a breast cancer diagnosis and prognosis by computer and to the value of aspiration cytologic examination of the breast into a statistical review of the medical literature [19].

5.3 Picture Archiving and Communication Systems

Medical services in current-time rely heavily on digital imaging technology due to image modalities utilised in medical field such as the computer Ecography, Mammography and MRI. These techniques require image-processing tools and digital management that has been the primary reason for development of Picture Archiving and Communication Systems (PACS) [25]. This technology provides economical storage and convenient access to images from multiple modalities where images are transmitted digitally via PACS where it eliminates the need to manually file, retrieve, or transport film jackets. The universal format for PACS image storage and transfer is Digital Imaging and Communications in Medicine (DICOM) [26] format.

The work that addresses the web based medical images, data processing and management systems, present an application of database and functional imaging [27] runs through the network and internet browser that has similar ability to the PACS yet having the advantages of being an online system can be viewed as archiving one step closer towards total online medical imaging system and online imaging in general. Despite the excellent information that this paper offer in the field of this research, we are more concerned with analysing the problem in a multimodality shed of image and interface surround, than this distribution of information side.

5.4 Computer Aided Diagnosis

The Picture Archiving and Communication System (PACS) [25] faces ever-growing adoption in hospitals and clinics worldwide [28] as we seen before. Digitalisation process and sharing of medical images is progressively replacing the use of tomography films, thus reducing costs and increasing the possibility of remote medical diagnosis through telemedicine solutions. Inline with this trend, Computer Aided Diagnosis (CAD) [29] is also gaining ground. CAD is an interdisciplinary technology combining elements of machine learning and computer vision with radiological image processing. A typical application is the detection of a tumor. For instance, some hospitals use CAD to support preventive medical check-ups in mammography (diagnosis of breast cancer). CAD typically intends to provide suggested diagnosis based on automatic quantitative analysis of medical images in order to aid physicians in their final diagnosis.

The output of ML based algorithms may be useful in situations where the human visual system might fail or in case of fatigue of the physicians, alerting on possible well-known problems. According to a computer-aided diagnosis in medical imaging article [29], there are two CAD system types. The first type of CAD system assists with lesion detection, searching for abnormal standards in images like micro-calcifications groups in mammography images. The second type of CAD system assists the diagnosis, analysing the quantification of image characteristics where extracting information about a lesion shape may help to determine if a tumor is malignant or benign.

5.5 Patient Visualisation

A two different interfaces to visualize patient histories on a PDA [30] describes two different users interfaces for mobile device tool that displays patient histories and permits to visually query patient data stored in hospital database.

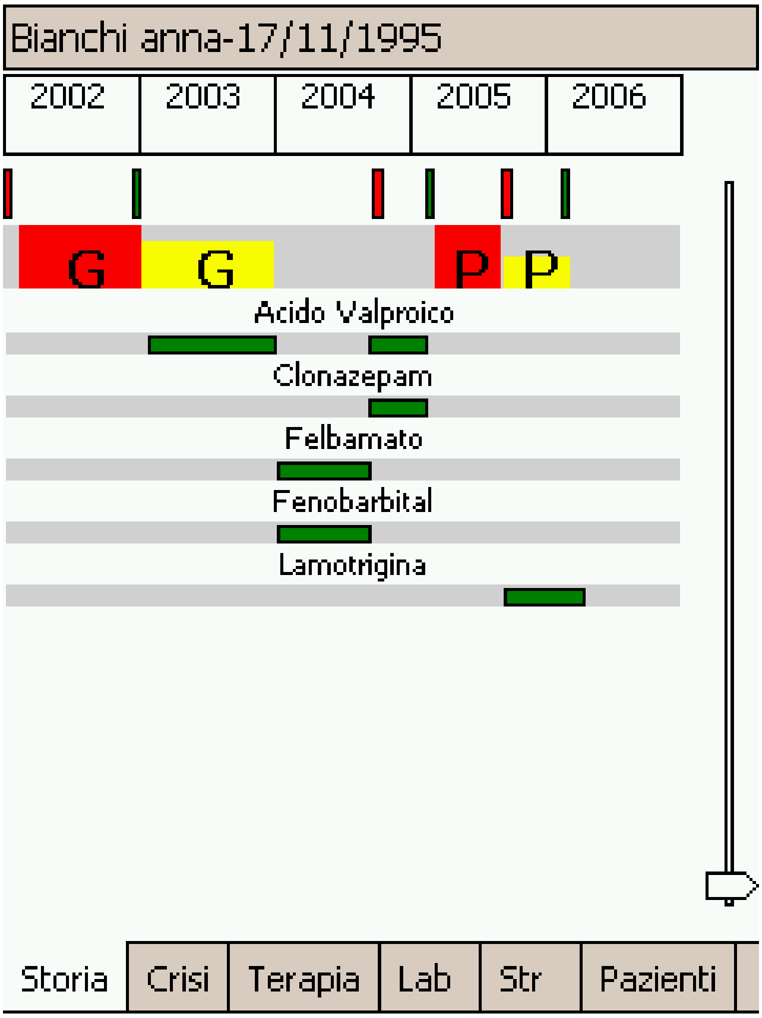

Figure 5.1: Zoomable interface of PHiP.

The objective of this work is to display as much as possible information about the patient history on a limited display space, providing overview data as well as details. By displaying on a single screen of a personal computer the overview of multiple facets of records will provide users with a better sense of type and volume of available data.

In fact, PHiP (Patient History in Pocket) [30] is a tool designed for a mobile device that displays patient histories and permits to visually query patient data stored in the hospital database exploiting information visualisation techniques where it is able to accommodate on the screen a good amount of clinical cases.

This work has been developed according to an user-centered approach and will bring MIMBCD-UI support in that way. Beside the user studies conducted in the hospital at the requirement phase, they have performed with doctors evaluations of the different prototypes and this kind of information is kindly useful for our research field as well.

5.6 Patient Progress

In computer-assisted creation of patient progress notes [31] a prototype application that supports the creation of critical care notes by physicians in a hospital of an intensive care unit, called activeNotes, integrates automated, context-sensitive patient data retrieval and user control of automated data updates and alerts into the note creation process.

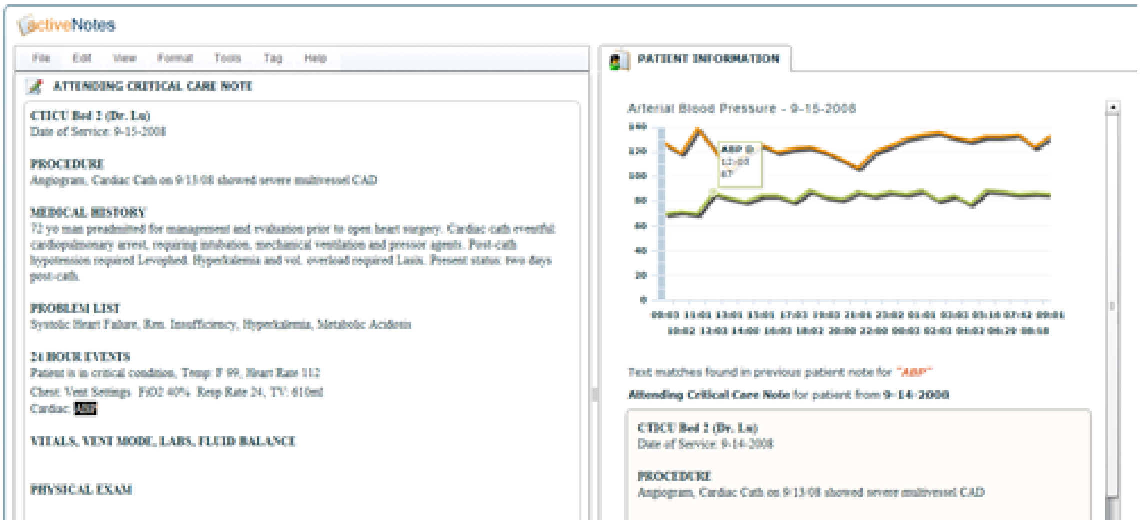

Figure 5.2: activeNotes Prototype System.

A critical care note is a clinical document, written by a hospital physician, that documents and patient's progress and prognosis. This kind of work will help MIMBCD-UI project by giving us information analyse by physicians feedback and user understanding. It also bring us information with qualitative study by providing us the right path throw prototype design and user experience evaluation.

The physician-driven management of patient progress notes in an intensive care unit [20], describes a design exploration focused on techniques to support data input and management of electronic progress note content. This will help MIMBCD-UI project by giving us an alternative design exploration including observations, structured and semi-structured interviews, design and implementation of a prototype, and feedback gathered in qualitative study with physicians surveys.

5.7 Interaction System

On M/ORIS: a Medical/Operating Room Interaction System [32] is proposed an architecture for a real-time multimodal system, which provides non-contact, adaptive user interfacing for Computer-Assisted Surgery (CAS) [33]. This paper focuses on the proposed activity monitoring aspects of M/ORIS. The researchers have analyse the issues of Human-Computer Interaction (HCI) in an Operation Room (OR) based on real-world case studies.

Figure 5.3: Operating room interaction system example.

5.7.1 CAS vs CAD

Computer Aided Surgery (CAS) [34] and Computer Aided Diagnosis (CAD) [35] can contribute to the general cost cutting trend in health care by making it possible to have fewer staff perform the same activity in less time than with traditional methods. It also brings us human error prevention and, if so, the system can better audit the source of problems and reduce error effects. In particular, it is likely that in the near future, a single doctor will have to control and diagnose several computer-based processes during a surgical, diagnosis or clinical intervention.

Efficient User Interface (UI) design that matches the constrains of clinical environments and that helps reduce the doctor's workload will, in a large part, determine the success of CAS and CAD.

5.7.2 User Interface for CAD

The impressive development of medical multimodality of imaging technology during the last decades provided physicians with an increasing amount of patient functional data and specific anatomical. Furthermore, the increasing use of non-ionising real-time imaging, in particular optical and ultrasound imaging, during cancer analysing procedures created the need for design and development of new visualisation of information and display technology [13] allowing physicians to take full advantage of rich sources of heterogeneous preoperative and intra-operative data. The medical augmented reality was proposed as a paradigm bringing new visualisation and interaction solutions into perspective.

CAD techniques, whether they enhance traditional methods (e.g. image visualisation [36]) or provide new tools such as augmented displays [13], share a common need for multimodality of imaging User Interface (UI). Interface issues are systematically brought up in connection with new computer-assisted techniques, and poor UI design is cited [32, 36] as significant limiting factor for many operations. In particular, doctors criticise the lack of user-centered design, the difficulty to operate computer-assisted equipment during surgery, and the failure to convey information without otherwise constraining the doctor.

To address these issues, several authors have developed guidelines for medical UI design. An introduction to human factors in medical devices [37] and making medical device interfaces more user-friendly [38] stress the importance of a doctor-centered design for both efficiency and human error reduction. A framework for determining component and overall accuracy for computer assisted surgery systems [39] proposes a framework for evaluating the benefits of new UI paradigms in CAS system design that can be applied to CAD system design.

5.8 Designing the User Interface

Multimodal systems that process user's speech and pen-based gestural input have become a vital and expanding field, especially within the past years, with demonstrated advances in a growing number of research and application areas.

A growing interest in multimodal interface design is inspired in large part by the goals of supporting more transparent, flexible, efficient and powerfully expressive means of human-computer interaction that in the past. Multimodal interfaces are expected to support a wider range of diverse applications, be usable by a boarder spectrum of the average population, and function more reliably under realistic and challenging usage conditions.

In designing the user interface for multimodal speech and pen-based gesture applications: state-of-the-art systems and future research directions [40] article, researchers summarise the prevailing and emerging architectural approaches available for interpreting dual input signals in a robust manner, including early and late semantic fusion approaches, as well as new hybrid symbolic-statistical architecture, that potentially are capable of archiving very robust functioning, for processing pen-voice input (i.e. speech and gesture). Researchers also described a diverse collection od state-of-the-art multimodal systems that are capable of processing user's actions input. This will brings an enormous added value in the implementation and architecture of our future user interface.

5.9 Usability and Ergonomic Testing

Semiotic analysis combined with usability and ergonomic testing for evaluation of icons in medical user interface [41] have evaluated the medical icons and iconic interfaces of touch screen ventilator systems used in Intensive Care Unit (ICU).

The use of icons in iconic user interfaces [42] in medical devices like ventilator systems is a common practice. Precise communications through iconic interface between ventilator system and medical users like physicians or nurses is critical to avoid medical errors which may cost patient's life.

This research will help us understand and defining a set of icons that will represent our metaphor analysis throw this work. It also, but not less, give us the right information about usability testing where icons can be tested using various usability testing methods. At last it will help us getting information about Semiotic and Lexical Analysis.

Semiotics is a study of cultural sign processes, analogy, signification, communication, metaphors, signs and symbols [43]. A semiotic analysis is concerned with meaning, which stems from relationships - in particular, the among signs relationships [44].

Linguistics has a term - 'Lexical Analysis' which is the process of converting a sequence of characters into a sequence of tokens. A lexical analysis helped in classification of medical icons [45] into mainly three classes: icons, indices and symbols.

Chapter 6

Another Class Of Devices

Mobile devices are increasingly being incorporated (Figure 6.1) onto Picture Archiving and Communication Systems (PACS). Previous work on medical image access using mobile devices essentially focuses on enabling the visualisation of the medical images at the mobile devices. In contrast, it can be proposed and developed a distributed system that allows medical image analysis using mobile devices. As a proof-of-concept, based on a mobile distributed system [46], which article develop a tool for dental implant simulation using mobile devices. There is also a discussion about the perspectives of extending the current system to incorporate Computer Aided Diagnosis (CAD) algorithms in it.

Figure 6.1: aycan mobile

Recently, mobile devices, such as PDAs, are being increasingly incorporated to PACS. Typically the flexibility on the visualisation of medical images storage in PACS, offered by a mobile access, is useful in patient care areas and emergency situations. This feature helps healthcare practitioners to have access to medical images at least for a preliminary image analysis in cases where searching for a dedicated terminal to access the images for a detailed and complete analysis is neither practical nor feasible.

The research proposes a distributed system that enables medical image analysis using mobile devices, as well as, the growth in the CAD area combined with the increase in processing power of the mobile devices and in the capacity of wireless networks favours the emergence of new developments integrating those technologies.

The communication between the mobile devices and the image server adopts web service technology [47]. To validate the distributed system processing power, speed, and feasibility we develop a tool for medical image analysis with mobile devices dedicated to assist in breast cancer visualisation diagnosis.

The deployed simulation tool allows the medic using a mobile device such as a PDA to determine the evolution of a patient like masses and calcifications location, preventing for instance the need for the doctor to move from analysis machine to the computer. After determine some critical areas, the doctor can visualise the analyse model of the result also using the mobile device. Results show that the use of mobile devices in hospital environments to assist the diagnosis and patient treatment is feasible. Other observation is that the mobile devices can be used to other tasks, like image model rendering, not only image visualisation.

Chapter 7

Conclusion

There is a lot of information concerning work in development for clinical user interfaces on images tools views, but, in fact, there is little in multimodality image and its display in breast cancer diagnosis fields.

This master project report is a first essay, to what will be the master thesis related work dissertation and state of the art [48]. It describe related systems that have been designed to provide more direct support and fundament to our research. We follow at most clinical imaging tools and personal computer-based interfaces as well as a hypothetical solution of implementation with mobile interfaces where it can help us understand the right user interface solution.

In short, we analyse and rehearsed what was the first approach to the subject-matter literature on a state of the art milestone of the project to understand and to investigate the various innovations and topics made in this field of research.

So far, there have been hardly any specific studies wherein the medical interfaces are tested and evaluated for their comprehensibility and usability to users. Pretty interfaces that hide the ugly reality of underlying data do not engender clinician trust and respect. New visual cues that provide immediate user insight into assumptions and deficiencies regarding the displayed information are required. Clinicians expect and interface to keep clear and direct with easy and intuitive usability.

Some requirements for advancing innovative imaging multimodality are not just intellectual ones, but rather social, political, and educational in nature. The development of state-of-the-art of multimodal images user interface of this kind also requires multidisciplinary expertise in a variety of areas, such as human factors and ergonomics [49], perception and graphics, linguistics, psychology, pattern recognition, statistics, engineering and computer science. The multidisciplinary nature of this research across the entire spectrum.

A review of the state of the art in the field is provided showing the increasing interest of researchers in the domain and a wide range applications where these methods can be applied.

Cancer is projected to become the world's leading cause of death by 2016, with the burden of disease shifting further towards medically underserved populations in industrialised countries and the developing world.

New approaches are required across the spectrum of cancer management, in prevention, diagnosis, treatment, education and care. If developed and tested appropriately, optical imaging technologies can play an important role in several aspects, from providing objective diagnostic screening at the community healthcare level, to enabling pathology guidance in the clinical setting.

Importantly, by delivering these technical capabilities within cost-effective platforms, the impact on public health can be magnified through expanding patient access to previously unreachable healthcare systems.

Bibliography

[1] R. L. Siegel, K. D. Miller, and A. Jemal, "Cancer statistics, 2016," *CA: a cancer journal for clinicians*, vol. 66, no. 1, pp. 7–30, 2016.

[2] NIH, "National cancer institute," 2016.

[3] W. A. Berg, J. D. Blume, J. B. Cormack, E. B. Mendelson, D. Lehrer, M. Böhm-Vélez, E. D. Pisano, R. A. Jong, W. P. Evans, M. J. Morton, *et al.*, "Combined screening with ultrasound and mammography vs mammography alone in women at elevated risk of breast cancer," *Jama*, vol. 299, no. 18, pp. 2151–2163, 2008.

[4] S. Lord, W. Lei, P. Craft, J. Cawson, I. Morris, S. Walleser, A. Griffiths, S. Parker, and N. Houssami, "A systematic review of the effectiveness of magnetic resonance imaging (mri) as an addition to mammography and ultrasound in screening young women at high risk of breast cancer," *European journal of cancer*, vol. 43, no. 13, pp. 1905–1917, 2007.

[5] S. G. Orel and M. D. Schnall, "Mr imaging of the breast for the detection, diagnosis, and staging of breast cancer 1," *Radiology*, vol. 220, no. 1, pp. 13–30, 2001.

[6] W. Teh and A. Wilson, "The role of ultrasound in breast cancer screening. a consensus statement by the european group for breast cancer screening," *European journal of cancer*, vol. 34, no. 4, pp. 449–450, 1998.

[7] O. L. Mangasarian, W. N. Street, and W. H. Wolberg, "Breast cancer diagnosis and prognosis via linear programming," *OPERATIONS RESEARCH*, vol. 43, pp. 570–577, 1995.

[8] K. P. Bennett and O. L. Mangasarian, "Robust linear programming discrimination of two linearly inseparable sets," 1992.

[9] O. L. Mangasarian, "Multi-surface method of pattern separation," 1998.

[10] W. H. Wolberg and O. L. Mangasarian, "Multisurface Method of Pattern Separation for Medical Diagnosis Applied to Breast Cytology," *Proceedings of the National Academy of Sciences,U.S.A.*, vol. 87, pp. 9193–9196, 1990.

[11] D. Cukier and J. W. Yoder, "The artist in the computer scientist: more humanity to our research," in *Proceedings of the 10th SIGPLAN symposium on New ideas, new paradigms, and reflections on programming and software*, pp. 129–136, ACM, 2011.

[12] M. G. Kahn, J. Coble, and M. Orland, "Keep no secrets and tell no lies: computer interfaces in clinical care," in *CHI 98 Cconference Summary on Human Factors in Computing Systems*, pp. 100–101, ACM, 1998.

[13] T. Sielhorst, M. Feuerstein, and N. Navab, "Advanced medical displays: A literature review of augmented reality," *Journal of Display Technology*, vol. 4, no. 4, pp. 451–467, 2008.

[14] J. E. BARDRAM and H. B. CHRISTENSEN, “Real-time collaboration in activity-based architectures,” in *Proceedings of 4th Working IEEE/IFIP Conference on Software Architecture (WICSA 04)*, pp. 325–329, 2004.

[15] V. M. González and G. Mark, “”Constant, constant, multi-tasking craziness”: managing multiple working spheres,” in *Proceedings of the SIGCHI conference on Human factors in computing systems*, CHI ’04, (New York, NY, USA), pp. 113–120, ACM, 2004.

[16] G. Mark, V. M. Gonzalez, and J. Harris, “No task left behind? examining the nature of fragmented work,” in *in: Proceedings of ACM CHI 2005, ACM*, pp. 321–330, ACM Press, 2005.

[17] M. Czerwinski, E. Horvitz, and S. Wilhite, “A diary study of task switching and interruptions,” pp. 175–182, ACM Press, 2004.

[18] G. Smith, P. Baudisch, G. Robertson, M. Czerwinski, B. Meyers, D. Robbins, E. Horvitz, and D. Andrews, “Groupbar: The taskbar evolved,” in *Proceedings of OZCHI 2003*, pp. 34–43, 2003.

[19] G. Robertson, E. Horvitz, M. Czerwinski, P. Baudisch, D. Hutchings, B. Meyers, D. Robins, and G. Smith, “Scalable fabric: Flexible task management,” 2004.

[20] G. Robertson, M. V. Dantzich, D. Robbins, M. Czerwinski, K. Hinckley, K. Risden, D. Thiel, and V. Gorokhovsky, “The task gallery: a 3d window manager,” pp. 494–501, ACM Press, 2000.

[21] C. Plaisant, D. A. Carr, and B. Shneiderman, “Image browsers: Taxonomy, guidelines, and informal specifications,” 1994.

[22] B. Shneiderman, “Designing the user interface (videotape),” 1987.

[23] J. E. Bardram, “Activity-based computing for medical work in hospitals,” *ACM Trans. Comput.-Hum. Interact.*, vol. 16, no. 2, pp. 1–36, 2009.

[24] A. M. Ahmad, G. M. Khan, S. A. Mahmud, and J. F. Miller, “Breast cancer detection using cartesian genetic programming evolved artificial neural networks,” in *Proceedings of the 14th annual conference on Genetic and evolutionary computation*, pp. 1031–1038, ACM, 2012.

[25] H. Oosterwijk, *PACS Fundamentals*. OTech, 2004.

[26] M. Mustra, K. Delac, and M. Grgic, “Overview of the dicom standard,” in *ELMAR, 2008. 50th International Symposium*, vol. 1, pp. 39–44, IEEE, 2008.

[27] J. Kim, D. D. Feng, and T. W. Cai, “A web based medical image data processing and management system,” in *Selected papers from the Pan-Sydney workshop on Visualisation-Volume 2*, pp. 89–91, Australian Computer Society, Inc., 2000.

[28] H. U. Lemke, “Pacs developments in europe,” *Computerized Medical Imaging and Graphics*, vol. 27, no. 2, pp. 111–120, 2003.

[29] M. L. Giger, “Computer-aided diagnosis,” *RSNA categorical course in physics*, pp. 283–298, 1993.

[30] C. Ardito, P. Buono, M. F. Costabile, and R. Lanzilotti, “Two different interfaces to visualize patient histories on a pda,” in *Proceedings of the 8th conference on Human-computer interaction with mobile devices and services*, pp. 37–40, ACM, 2006.

[31] L. Wilcox, J. Lu, J. Lai, S. Feiner, and D. Jordan, “Activenotes: computer-assisted creation of patient progress notes,” in *CHI’09 Extended Abstracts on Human Factors in Computing Systems*, pp. 3323–3328, ACM, 2009.

[32] S. Grange, T. Fong, and C. Baur, "M/oris: a medical/operating room interaction system," in *Proceedings of the 6th international conference on Multimodal interfaces*, pp. 159–166, ACM, 2004.

[33] H. K. Hahn, B. Preim, D. Selle, and H.-O. Peitgen, "Visualization and interaction techniques for the exploration of vascular structures," in *Visualization, 2001. VIS'01. Proceedings*, pp. 395–578, IEEE, 2001.

[34] Wikipedia, "Computer-assisted surgery," 2016.

[35] Wikipedia, "Computer-aided diagnosis," 2016.

[36] F. Vogt, S. Krüger, H. Niemann, and C. Schick, "A system for real-time endoscopic image enhancement," in *International Conference on Medical Image Computing and Computer-Assisted Intervention*, pp. 356–363, Springer, 2003.

[37] D. Sawyer, K. Aziz, C. Backinger, E. Beers, A. Lowery, and S. Sykes, "An introduction to human factors in medical devices," *US Department of Health and Human Services, Public Health Service, Food and Drug Administration, Center for Devices and Radiological Health*, 1996.

[38] M. E. Wiklund, "Making device interfaces more user-friendly," *Medical Device and Diagnostic Industry*, vol. 20, pp. 177–183, 1998.

[39] A. B. Mor, J. Moody, D. Davidson, R. S. LaBarca, B. Jaramaz, and A. Digioia III, "A framework for determining component and overall accuracy for computer assisted surgery systems," in *International Conference on Medical Image Computing and Computer-Assisted Intervention*, pp. 985–986, Springer, 2003.

[40] S. Oviatt, P. Cohen, L. Wu, L. Duncan, B. Suhm, J. Bers, T. Holzman, T. Winograd, J. Landay, J. Larson, *et al.*, "Designing the user interface for multimodal speech and pen-based gesture applications: state-of-the-art systems and future research directions," *Human-computer interaction*, vol. 15, no. 4, pp. 263–322, 2000.

[41] G. Bhutkar, R. Poovaiah, D. Katre, and S. Karmarkar, "Semiotic analysis combined with usability and ergonomic testing for evaluation of icons in medical user interface," in *Proceedings of the 3rd International Conference on Human Computer Interaction*, pp. 57–67, ACM, 2011.

[42] K. Dinesh, "Experimenting with uniface: A tool for usability testing of icons," in *Proceedings of National Usability Conference, Easy 2004, Bangalore, India*, ACM-SIGCHI-SI, 2004.

[43] Wikipedia, "Semiotics terminology," 2010.

[44] "Berger final pages," 2010.

[45] R. Poovaiah, "Graphics symbols for environmental signage: A design perspective," *A design Perspective, IDC Publication*, pp. 29–42, 1997.

[46] B. Correa, E. Ishikawa, A. Ziviani, and M. Faria, "Medical image analysis using mobile devices," in *Proceedings of the 2008 ACM symposium on Applied computing*, pp. 1380–1384, ACM, 2008.

[47] W3C, "Web Service activity," 2002.

[48] T. Borchers, *Persuasion in the media age*. Waveland Press, 2012.

[49] Wikipedia, "Human factors and ergonomics," 2016.

Appendix A

Appendix chapter

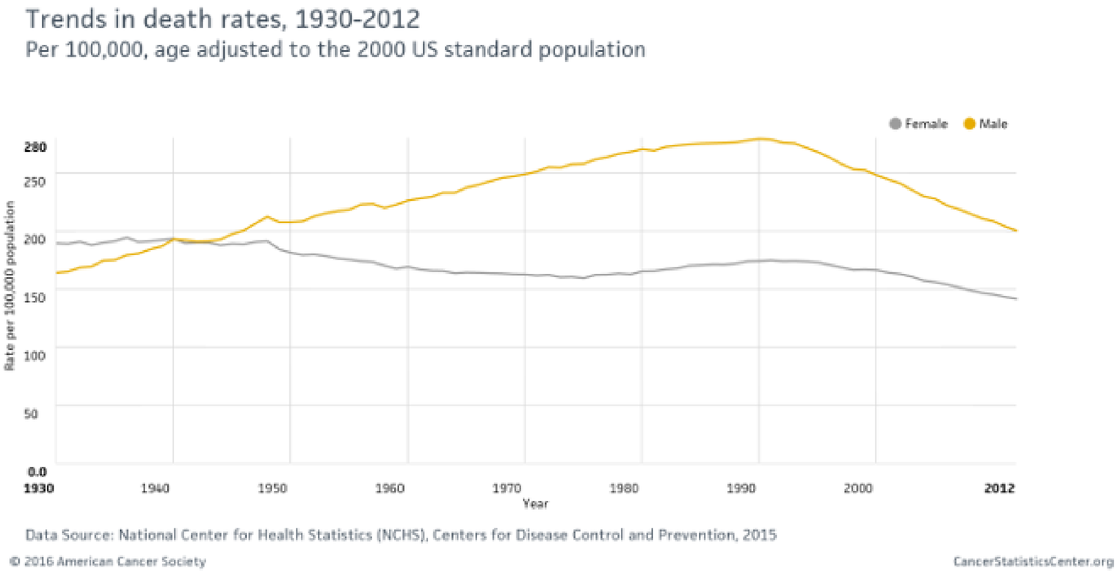

Figure A.1: Thrends in death rates.

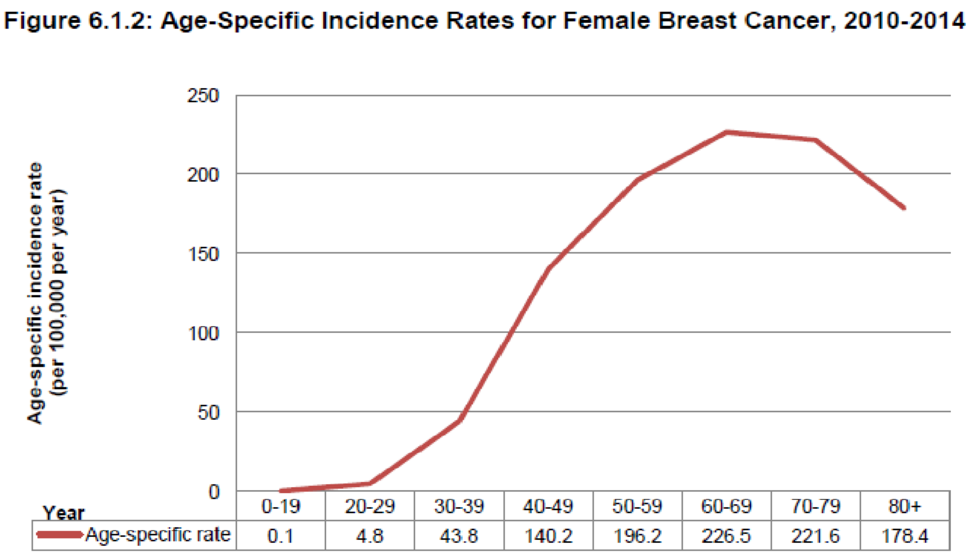

Figure A.2: Age-Specific Incidence Rates.

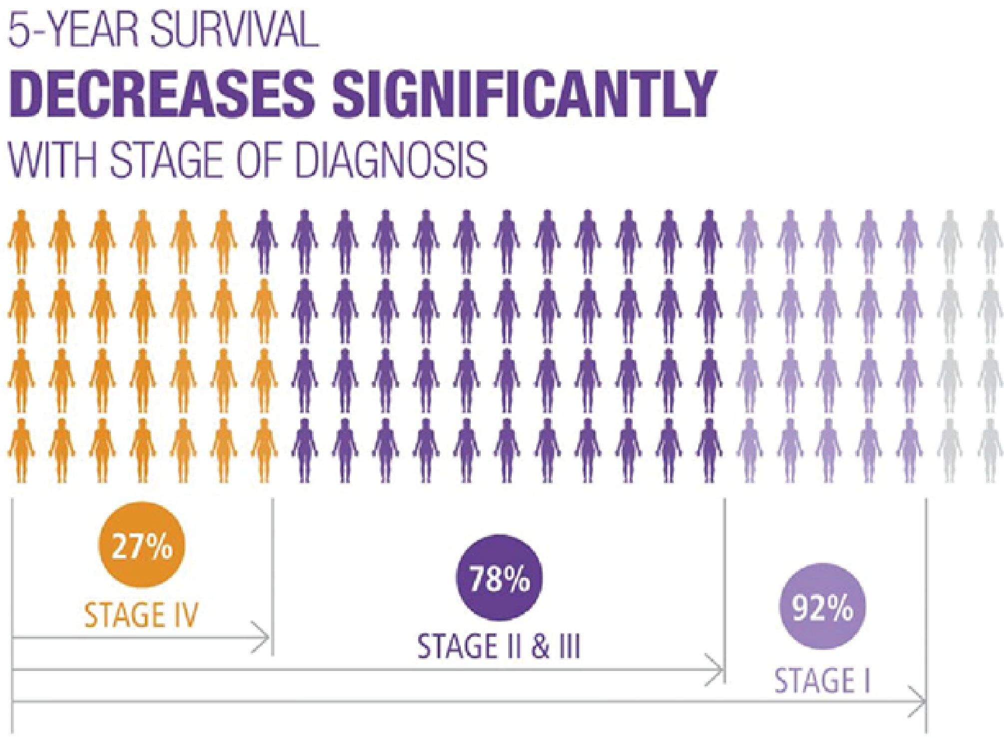

Figure A.3: Stage of diagnosis.

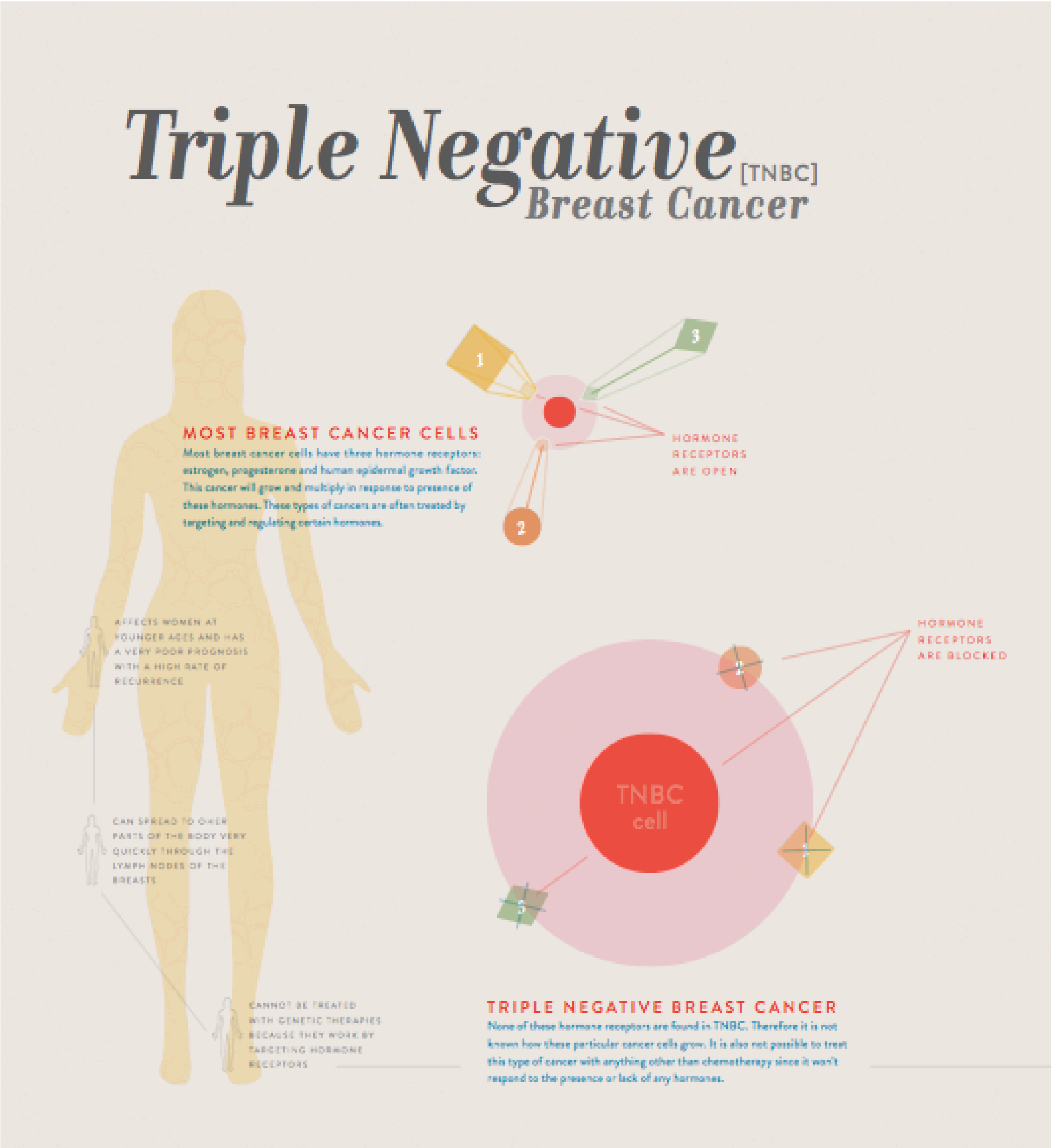

Figure A.4: Triple negative.