Implementation of medical imaging with telemedicine for the early detection and diagnoses of breast cancer to women in remote areas

Alphonsine Imaniraguha

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Implementation of Medical Imaging with Telemedicine for the Early Detection and Diagnosis of Breast Cancer to Women in Remote Areas

By Alphonsine Imaniraguha

A Thesis Research submitted in Partial Fulfillment of the Requirements for the degree of Masters of Science in Telecommunications Engineering Technology

Rochester, New York, United States

November 2008
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November 2008
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Preface

In the summer of 2007, I worked with Dr. Chance M Glenn Sr., a professor at Rochester Institute of Technology (RIT), in the department of Telecommunications Engineering Technology (TET) as Graduate Research Assistant in the McGowan Center for Telecommunications Innovation and Collaborative Research; we explored and implemented his new image algorithm compression tool (DYNAMAC: Dynamics Algorithm based Compression) based on Dynamical Nonlinear Systems (chaotic oscillators). We applied this algorithm to process and scan lung images to generate the cancer average profile for future implementation and applications in medical imaging; the project had run successfully. Over the time, I developed an interest; I always felt I could be creative to come up with a project plan that can benefit to people who live in critical conditions.

Therefore, I decided to explore this algorithm to women in remote areas who suffer from breast cancer; hence, there came this thesis topic. This research sums up the knowledge I acquired in Telecommunications and Networking over several years, taking into account the modern technology in health care specifically in medical imaging, altogether with the Telemedicine which is the intelligence of sharing medical and clinical information over a distance. With this, I felt like my dream was being realized; I will finally propose a project that women in developing countries and isolated rural areas can benefit from. I would deeply like to thank Dr. Chance M Glenn Sr. for allowing me to use a part of his work for my thesis research.
Abstract

Nowadays, the cancer topic has become a global concern. Furthermore, breast cancer persists to be the top leading cause of death to women population and the second cause of cancer death after the lung cancer globally. Various technologies and techniques have been searched, developed and studied over the years to detect the disease at the early stage; the early diagnosis saves many lives in both developed and developing countries. The detection of cancer through a screening process before its symptoms emerge increases the survival rate dramatically (Li, Meaney and Paulsen). Moreover, sufficient knowledge of the disease, qualified staff, accurate, appropriate treatment and diagnosis contribute to the successful cure of the disease; however, the cancer treatment is not affordable by many and sometimes not available to the very needy, and more precisely in developing countries.

In this research, we aimed to explore the early detection of breast cancer using the new image compression algorithm: DYNAMAC, a compression tool that finds its basis in nonlinear dynamical systems theory; we implemented this algorithm through the D-transform, a digital sequence used to compress the digital media (Wang and Huang) & (Antoine, Murenzi and Vandergheynst). The goal is to use this method to analyze the average profile of diseased and healthy breast images obtained from a digital mammography to detect diseased tissues. After the detection of cancerous tumors, we worked to establish a remote care to women victims of breast cancer using the Telecommunication infrastructure through primarily Teleradiology and the Next Generation Internet (NGI) technology. Over the methods and techniques previously used in the area of medical imaging techniques, DYNAMAC algorithm is the most easily implemented along with its features that include cost saving in addition to best meeting the requirements of the breast imaging technology.

Key words: DYNAMAC Algorithm, Breast Imaging, Mammography, Telemedicine
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I owe my most and special appreciation to Ms. Renee Morgan, the Clinical Research Coordinator, Elizabeth Wende Breast Care (EWBC), Rochester, New York, for her mighty heart and kindness when I hopelessly approached her in May 2008, searching for breast images collection. Her co-workers, Melissa Skolny, the Clinical Research Assistant and Andrea Arieno, the Research Coordinator, for their help and allowing me to use their data for my research; they all deserve my recognition.

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God bless you all.
Dedication

In the memory of the family members that I lost in the 1994 Rwanda Genocide:

My father Alphonse, my mother Colette,

My brother Jean Felix and my sister Marie Claudine.

My success has always been your pride, I love you forever.
List of Acronyms

**DYNAMAC**: Dynamics Algorithm based Compression

**NGI**: Next Generation Internet

**ACS**: American Cancer Society

**NCI**: National Cancer Institute

**2-D**: Two dimensional

**3-D**: Three dimensional

**NGN**: Next Generation Networks

**MRI**: Magnetic Resonance Imaging

**ANN**: Artificial Neural Networks

**CAD**: Computer Aided Diagnosis

**FSWC**: Fourier Series Waveforms Classification

**DNA**: Deoxyribonucleic Acid

**BRCA1 & 2**: Pair of genes involved in Breast Cancer

**BSE**: Breast Self-Examination

**CBE**: Clinical Breast Examination

**PET**: Positron Emission Tomography

**FFDM**: Full-Field Digital Mammography

**EWBC**: Elizabeth Wende Breast Care

**TII**: Thermal Infrared Imaging

**CCO**: Combined Chaotic Oscillators

**DICOM**: Digital Imaging and Communications in Medicine

**GUI**: Graphic User Interface

**WHO**: World Health Organization

**E-health**: Electronic health

**NASA**: National Aeronautics & Space Administration
**STARPAHC:** Space Technology Applied to Rural Papago Health Care

**ITV:** Interactive Teleconference

**S&F:** Store-and-Forward

**ISDN:** Integrated Services Digital Network

**PRI-ISDN:** Primary Rate Interface ISDN

**BRI-ISDN:** Basic Rate Interface ISDN

**B-ISDN:** Broadband ISDN

**IP:** Internet Protocol

**PSTN:** Public Service Telephone Network

**ATM:** Asynchronous Transfer Mode

**DSL:** Digital Subscriber Line

**SONET:** Synchronous Optical Network

**SDH:** Synchronous Digital Hierarchy

**MPLS:** Multi Protocol Label Switching

**ISP:** Internet Service Providers

**LAN:** Local Area Network

**IEEE:** Institute of Electrical and Electronic Engineers

**CSMA/CD:** Carrier Sense Multiple Access with Collision Detection

**FDDI:** Fiber Distributed Data Interface

**CATV:** Cable Television

**HSCC:** High Speed Connectivity Consortium

**OC:** Optical Carrier

**FD:** Fibre Channel

**SAN:** Storage Area Network

**VPN:** Virtual Private Network

**WAN:** Wide Area Network

**MAN:** Metropolitan Area Network
**GSM**: Global System for Mobile Communications

**CDMA**: Code Division Multiple Access

**WLAN**: Wireless LAN

**TATRC**: Telemedicine and Advanced Technology Research Center

**VSAT**: Very Small Aperture Terminal
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1. Introduction

Several world and national non-profit organizations have engaged in finding day to day solution to cancer deaths. However, a considerable number of women victims of breast cancer have persisted. For 2008, the American Cancer Society (ACS) and the National Cancer Institute (NCI) estimated 182,460 new breast cancer cases and about 40,480 will die of breast cancer in the United States (Breast Cancer New Cases and Deaths). This is a big number taking into account the modern technology and the availability of advanced research institutions. More precisely, women in developing countries represent a substantial number of women who die from breast cancer every year due to a lack of the improved early detection and diagnosis methods with the appropriate equipment.

Conventional mammography which is an x-ray imaging (2-D) has been the effective method to detect breast cancer tumors at the early stage; it has significantly contributed to the decrease of the death rate through mammography screening. Film mammography has been in use for a long period of time; however, it is less sensitive to women with dense breast tissues due to the film contrast itself (Bassett and Gold). Digital mammography is a technique that consists of storing breast images in digital form on the computer using less radiation; with this method, images can be sent electronically, manipulated and clinically interpreted using software tools to improve the quality (Bassett and Gold). More importantly, radiologists can use different image processing techniques to modify and provide more accurate interpretation about clinical conditions of images.

In this research, I looked up on to previous research done on breast cancer screening using different types of image processing, storage and compression tools and techniques to
contribute to the early detection and diagnosis of the disease. This paper illustrates the use of the three dimensional (3-D) imaging to improve the interpretation of digital breast images; three dimensional mammographic imaging makes the ease of exploit the interior of the breast and overlapping tissues (Cahoon, Sutton and Bezdek). With this knowledge, we implemented a digital image compression tool, the DYNAMAC Algorithm to scan x-ray breast images obtained from a digital mammography; DYNAMAC originates in Dynamical Nonlinear Systems, more precisely, chaotic oscillators. This algorithm has been explored through scanning and processing a number of breast images from digital mammography, both diseased and healthy. Hence, we analyzed the average profile obtained from various image sample profiles to detect cancerous tissues; the stored average cancer profile has served to compare and detect masses from the rest of images. This tool seems to not only be easily manipulated but also cost saving.

Developed countries and various non-governmental organizations along with the World Health Organization (WHO) have also embarked in promoting the health care through funding medical related topics particularly in developing countries, where there is a limited access to hospitals and the appropriate medical care is not always available. Considering the current technology infrastructure with the next generation networks (NGN) for broadband usage, this research has demonstrated how Telecommunications equipments and broadband networks can be combined to provide health care remotely (Telehealth) to women in isolated areas through Teleradiography (remote transmission); while a considerable small number of men can also acquire the breast cancer disease, this paper illustrates in particular women victim of breast cancer.
This thesis research consists of six sections: Section one is the introduction of the paper which summarizes what has been previously done in order to improve the early detection of breast cancer, the leading cause of cancer death among women population around the globe and the second leading cause of death after the lung cancer. The American Cancer Society estimates that 1 of every 11 women will get cancer of the breast during her lifetime; the incidence is considered so common that every 15 minutes, three women develop breast cancer and one woman dies of the disease (Daffner). The real cause of breast cancer still remains unknown; therefore, it is very important to improve the early detection mechanisms to prevent and drop the death rate. In addition, women need to be educated about the disease and consult doctors on a regular basis especially women at higher risk of breast cancer.

Section two details the background information of the breast cancer; the breast anatomy, the normal and abnormalities to educate women and encourage them to have a breast self examination done on a regular schedule. This section also specifies the types of breast cancer: microcalcifications and masses along with the difference between malign and benign breast; it provides elemental education about the disease, causes, symptoms, diagnosis as well as suggestions for women to be aware of their breast anatomy. It also gives theory of x-ray and image production, the master point of this thesis research and the medical imaging key to the mammography. The main difference and evolution of breast imaging from Film-Screening mammography (2-D) to Digital Mammography (3-D) and its application to breast cancer early detection and diagnosis are provided below in this section; screening and diagnosis mammography are also mentioned and explained in details with their use.
Section three of this work is the thesis statement which is the brief summary of this research work; image compression using DYNAMAC-Biomed Algorithm to further diagnose the nature of x-ray mammogram images to generate a general idea of cancerous tumors detection from various tissues of the breast image samples. This section also conveys the further implementation of this medical imaging algorithm tool along with next generation broadband networks to bring facilities to women in isolated areas. Previous research and studies done in the area breast imaging using digital image processing techniques to improve the accurate interpretation of breast images are also mentioned in this summary; those range from Artificial Neural Networks, which shows how long the disease is supposed to recur after the surgery to Microwave Imaging, MRI and Computer Aided Detection (CAD) to name few. (Tierney, McPhee and Papadakis)

Section four is the core part of this paper; methods and approach for the early detection of breast cancer are based upon the breast imaging and the Computer Aided Diagnosis techniques: DYNAMAC Algorithm which finds its basis in Nonlinear Dynamical Systems. This algorithm has been studied and previously tested on lung cancer images. We successfully developed an average profile of lung cancer x-ray images and we analyzed the results. Similarly, to generate the average breast cancer images profile, we used the D transform, a digital sequence to match the corresponding waveforms inside the chaotic oscillation matrix using Fourier Series Waveforms Classification (FSWC) technique; the stored average cancer profile has served to compare the rest of images to detect diseased and healthy tissues by revealing the likeness and the differences. Section five of this paper is the analysis and the simulation of the results found in the previous section to emphasize and investigate on the
accuracy and the use of the DYNAMAC Algorithm; it interprets the resemblances and
distinctions found in processed and scanned images.

Section six is the application part of this paper, Telemedicine through mainly
Teleradiology; however, the real time application is also mentioned in this chapter for future use
when needed. This section also details the history and defines telemedicine with its use from
early 1900 until recently. It mentions real time and store-&-forward techniques used to share
radiological images; broadband networks have contributed the success transmission of
information of any form. It is in the same way, this work has used the Next Generation Network
to suggest a deployment of a remote assistance and enable Telehealth care to women in isolated
areas. This section shows the picture of how DYNAMAC can be explored to achieve the
appropriate treatment to women victims of the breast cancer disease. Section seven is the
recommendation and future work suggestions which point out the use of DYNAMAC algorithm
to study other types of cancer. This research work has also the appendix for the additional
information about the images processed below.
2. Background information

This section consists of the overview and the general information about the breast and its anatomy, the normal and abnormal composition, X-ray production, conventional mammography and breast imaging. It also details the theory of breast cancer, its symptoms and causes along with the diagnosis through the mammography procedure. This chapter also lists the suggestions and tips for women at higher risks of breast cancer; for instance, a screening mammogram to every women especially middle age and aged women.

2.1 Anatomy of the breast

Figure 1: Anatomy of the female breast (Interactive Mammogram Analysis Web Tutorial: Anatomy of the Female Breast)
Breasts are conical structures lying on the anterior and lateral chest wall. In general, the second or third rib (level of the clavicle) marks the superior boundary of the breast which extends inferiorly the sixth or seventh rib. Usually the breast extends from the lateral border of the sternum to the mild-axillary line, but occasionally to the midline or the anterior border of the latissimus dorsi (Breast Cancer).

Breast size and weight vary among individuals and with the same individuals at different period of her life. The breasts are generally 10-12 cm long and 3-5 cm thick. The breasts are small in size before the puberty, enlarge with the generative organ development, increase in size during pregnancy and especially after delivery and become atrophic at the old age. The left breast is generally larger than the right breast. (Harper)
2.1.1 Normal breast composition

The anatomy of the adult female breast consists of 12 - 20 conical lobes. The base of a lobe lies on top of the pectoral muscles and ribs, and its apex is at the areola and nipple. Lobular (glandular) and ductal tissue lie within each lobe supported by intralobular connective tissue and adipose tissue. There is also extralobular connective tissue which binds the lobes together as well as extralobular adipose tissue. Adipose tissue is radiolucent, and the radiographically visible densities on a mammogram are the images of lobular elements, ducts, and fibrous connective tissue. Ducts may be seen as thin linear structures emanating from the nipple. Lobules and their ducts are often superimposed with connective tissue structures. Whether the

Figure 2: Schematic diagram of the female breast (Interactive Mammogram Analysis Web Tutorial: Anatomy of the Female Breast)
mammographic appearance of a breast will appear more or less radiolucent will depend for the most part on the quantity of extralobular connective tissue. (Anatomy of the Female Breast)

2.1.2 Abnormalities of a breast

Women breast changes may occur during menstrual cycle, pregnancy or aging period. Breast lumps which are any unusual change in women breast may be malignant (cancer) or benign (not cancer); breast abnormalities can be divided into 2 categories: breast masses (lumps) and micro- calcifications (Abnormalities of a Female Breast).

2.1.2.1 Breast masses

Mass: defined as a dense space occupying lesion seen on two different projections with convex outer borders. It is usually denser in the center than the periphery. Its margins may be sharp & circumscribed (benign cyst) or spiculated, lobulated/undulating, indistinct or obscured suggestive of malignancy. Circumscribed margins are sharply demarcated with an abrupt transition between the lesion and surrounding tissue, with nothing to suggest infiltration and are a reassuring characteristic. Spiculated margins on the other hand are suggestive of surrounding parenchymal infiltration (Abnormalities of a Female Breast). Benign breast tumors are abnormal growths that have not spread outside of the breast to other organs. They are not life threatening. They are easily removed and usually do not come back. Benign growths include fibroadenomas (a ball of fibrous tissue) and cysts. (Abnormalities of a Female Breast). There are two types of breast masses: shapes and margins.
2.1.2.2 Microcalcifications

Microcalcifications are very small specks of calcium that cannot be felt, but can be seen on a mammogram. They are formed by rapidly dividing cells. These microcalcifications might be an early sign of breast cancer, when they are clustered in one area of the breast.
Microcalcifications can also be an indication of benign breast scar tissue; they can result from nursing or injury. Microcalcifications do not reflect excess calcium in one's body. Sometimes they can point to a suspicious area which contains cancer cells. This requires biopsy and examination under the microscope. (Abnormalities of the female breast)

2.2 Breast Cancer

2.2.1 Definition

As I talk about cancer and breast cancer in particular, it is very important for every human race (especially women) around the globe to learn about it to be able to adopt precautions and take a step forward to fight against its consequences and relay its symptoms. **What is cancer?**

According to the National Cancer Institute (NCI), cancer is defined as “a term for diseases in which abnormal cells divide without control. Cancer cells can invade nearby tissues and can spread to other parts of the body through the blood and lymph systems” (Breast Cancer). Breast cancer, also as defined by NCI, is “Cancer that forms in tissues of the breast, usually the ducts (tubes that carry milk to the nipple) and lobules (glands that make milk). It occurs in both men and women, although male breast cancer is rare”. (Breast Cancer)

Inside the human body, normal cells grow, divide and die systematically from the early years of a person’s life until he becomes adult. After this stage, in most parts of the body, cells only divide to outlive and replace the injured ones. Similarly, cancer (abnormal) cells grow and divide; although instead of dying, they continue surviving and travel to other parts of the body and destroy normal tissues to replace them, unlike normal cells. This is called “metastasis”, which happens when cancer cells invade in blood and lymph cells of our body (Breast Cancer).
In the normal body, when DNA becomes damaged, our body is usually able to repair it, whereas, DNA cannot be repaired in cancer cells; which makes the body weaker and weaker.

### 2.2.2 Asymptomatic and Symptomatic women

Cancer of the breast is the major health problem in the lives of women. Only one factor remains of undisputed importance: the early diagnosis. It is advisable for every woman to have a regular breast screening exam to be able to know where their life stands.

#### 2.2.2.1. Asymptomatic Women

1. Women 20 years of age and older should perform breast self examination on weekly basis.

2. Women aged 20 to 40 should, in addition, have a physical examination of the breast every 3 years. Women aged 40 or older should have a breast physical examination on the yearly basis.

3. Women aged 35 to 39 should have a baseline mammogram. Women aged 40 – 49 should have a mammogram performed every 1 to 2 years.

4. Women 50 years of age and older should have a mammogram exam every year. (Daffner)

#### 2.2.2.2 Symptomatic Women

Symptomatic women with a dominant breast mass, persistent discomfort, or nipple discharge, should have a thorough breast examination that includes mammography and any other diagnostic study (ultrasound) to determine if cancer is present. These studies should be performed regardless of the patient’s age. (Daffner)
2.2.3 Causes and Symptoms

2.2.3.1 Causes

The cause of the cancer of the breast and cancer in general remains unknown. However, the ACS determines certain risk factors that are linked to the disease. Each type of cancer has its own risk factors and some may be changed; for instance, drinking, smoking, dieting routines etc. However, there are others that cannot be changed, such as race, age, family history etc. As far breast is concerned, hormones play an important role in developing breast cancer from the above mentioned risk factors, but how that happens is not yet fully understood. Some factors that might increase the chances of having breast cancer are listed below (What Causes Cancer):

(a) **Gender**: Just simply being a woman is being at risk of getting breast cancer. While men can also get the disease, the chances are very minimal, less than a hundred times to women.

(b) **Age**: The chances of having breast cancer are higher to older women. 2 out of 3 women that have been diagnosed and found to have cancer are at least aged at least of 55 or older.

(c) **Genetic risk factors**: About 5% - 10% of breast cancers are thought to be linked to mutation (changes) in certain genes; for instance, BRCA1 & BRCA2. Women who have those gene changes have up to 80% risks of getting breast cancer during their lifetimes. Other gene changes might cause breast cancer risks as well.

(d) **Family history**: Women whose close blood relatives have/had this disease have high risks of developing breast cancer during their lifetimes.
(e) **Personal history of breast cancer:** A woman with cancer in one breast has greater chances of having cancer in the second breast too.

(f) **Race:** White women are likely to get breast cancer than African-American women; however, African American women are more likely to die of this disease. The reason is, African-American women have a faster growing tumor. White women have less chances of developing this disease.

(g) **Abnormal breast biopsy:** Certain types of abnormal breast biopsy may cause breast cancer.

(h) **Menstrual periods:** Women who begin having periods at less than 12 years old or have a menopause after 55 have slightly high risk of developing breast cancer in their lifetime.

(i) **Early breast radiation:** Women who have radiation in the chest area as a result of treatment of another cancer has high chances of developing breast cancer.

(j) **Treatment with DES (Diethylstilbestrol):** Some pregnant women in the past were given DES in order to avoid miscarriage. Studies have shown that, mother and babies in the womb are at high risk of getting breast cancer.

(k) **Not having children or having them later in life:** Having the first child after age 30 and older or having none increase risks of breast cancer.

(l) **Birth controls pills:** Studies have shown that women who have used birth control pills have greater chances of developing breast cancer than those who never used them.
(m) **Breast feeding and pregnancy:** Studies have shown that, the longer a woman breastfeeds her baby, the lesser chances of having breast cancer she has. This is because, while breastfeeding as well as pregnancy, you get the lower total number of menstrual periods of women.

(n) **Alcohol:** The ACS suggests limiting the amount of alcohol drinking since the alcohol is clearly linked to the breast cancer.

(o) **Obesity:** The ACS has shown that being overweight especially in older ages increases the risks of developing cancer of the breast.

(p) **Exercising:** Like any other health issue, it is important to exercise since it lowers the chances of having breast cancer.

Other causes that are not mentioned above can be found at the American Cancer Society (ACS) website. Those consist of uncertain causes that do not have proofs but still considered to be the cause of cancer of the breast; those factors includes but not limited to pollution, tobacco smoke, night work etc. (What Causes Breast Cancer)

### 2.2.3.2 Symptoms

Breast cancer continues to be a major cause of death from malignancy in American women and the rest of the world. There are two main types of breast cancer to note the common one that is **ductal carcinoma** that starts in the tubes (ducts) that carry milk to the nipples and **lobular carcinoma** that starts in lobules that produce milk. (NY Times, Health Guide, Breast Cancer 2007). In the early stages, breast cancers are usually painless, have even edges and
mostly located in the outer quarter of the breast. The most common sign of breast cancer is a new lump or mass; other typical signs include but not limited to:

- change in the size (swelling)
- shape
- skin irritation or dimpling
- breast pain
- nipple pain or the nipple turning inward
- redness
- scariness
- thickening of the nipple or breast skin
- nipple discharge (bloody, clear-to-yellow or green)
- A lamp in the underarm area (Breast Cancer Symptoms)

The advanced cancer symptoms might include also bone pain, breast pain or discomfort, skin ulcers, swelling of one arm, weight loss etc.

### 2.2.4 Treatment and Diagnosis

Breast cancer persists to be a health issue to women’s lives, not only being the frequent cancer in women, but also being the leading cause of their death; *although the new knowledge has led to a changing philosophy in its management, one and only one factor remains undisputed: early diagnosis* (Bassett and Gold). The early detection and diagnosis of breast cancer and other cancers in general is the key role to the survival rate increase; screening methods include breast self-examination (BSE), clinical breast examination (CBE) and
screening mammography. This paper mentions some of the previous research that has been conducted in the same area using various methods. Conventional mammography, recently improved to a new technology, digital mammography (2D to 3D) used in this paper, continues to be the best method through screening to detect breast cancer before its symptoms emerge. The ACS recommends every women to have a regular mammogram exam especially women at high risk of breast cancer (Breast Cancer).

Lately, medical imaging through bioinformatics have been incorporated and supported by research institutions in collaboration with NCI & ACS in order to promote the profound exploration of produced breast images from x-ray (mammogram), MRI, PET etc. It is in the same context that, this study investigates the detection of cancerous tissues from x-ray mammogram images using the new tool: DYNAMAC algorithm to distinguish health and diseased breast tissues. Furthermore, women patients who suffer from the disease can be taken care of using this new tool through Teleradiology, which requires advanced medical equipments and relatively high speed internet connection to facilitate the offline work by doctors and radiologists. Therefore, women in remote areas and underprivileged can benefit from the Telehealth technology through the appropriate equipments in combination with this new image compression tool; at the end user, there should be an x-ray mammography which will serve to take digital images. Hence, images will be sent remotely to the other end where a doctor will examine the progress of patient offline.
2.3 X-ray and images production

2.3.1 X-ray production and its implementation

X-rays are a form of electromagnetic radiation or energy of extremely short wavelength; they are described in terms of particles or packets of energy called quanta or photons. Photons travel at the speed of light, the energy carried by each photon depends on the wavelength of the radiation which is measured in electron volts (eV). An electron volt is the amount of energy that an electron gains as it is accelerated through a potential of one volt. X-rays are used in diagnostic radiology require a vacuum and the presence of a high potential difference between a cathode and an anode. In the x-ray tube, electrons are boiled off the cathode by heating it to a very high temperature. To move electrons toward the anode at energy sufficient to produce x-rays, a high potential up to 125 kV is used. When the accelerated electrons strike the tungsten anode, then x-rays are produced (Daffner).

2.3.2 Image production

Image production is achieved through x-rays results from the attenuation of these x-rays by the material through which they pass. Attenuation is the process by which x-rays are removed from a beam through absorption and scatter. In general, the greater the density of the material (the number of grams per cubic centimeter, the greater is its ability to absorb or scatter x-rays (optional figure). The absorption is also influenced by the atomic number of the structure; the dense the structure, the greater the attenuation, and the lesser blackening (radiographic contrast) of the film. The image quality depends on the physical and geometric factors that affect the radiographic image; this includes the thickness of the part being irradiated, motion, scatter, magnification and distortion (Daffner).
2.4 Mammography

The actual absolute cure to breast cancer is the early detection before its symptoms. Mammography remains the most valuable and single successful technique for the early detection of breast cancer in breast imaging; a mammogram is a low dose an x-ray (radiography) picture or mammography exam of the breast. X-ray mammography is the only proven method capable of detecting nonpalpable cancers (Breast Cancer Detection, Lawrence). Studies have shown that the mammography exam is a lot easier to women with fatty breasts than those with dense breasts (Breast Cancer). There are two types of mammograms: (a) Screening mammogram used to early detect breast cancer before its symptoms and (b) Diagnostic mammogram used to evaluate patients with abnormal clinical findings and under treatments of breast cancer.

Figure 5: A standard Mammography Unit (Mammography Unit)
The quality of a mammogram image is based on various factors: the nature and accessories of the mammography unit, the use photographic film for image acquisition, storage and display; although films provide very high resolutions and good visibility of high contrast structures, the signal contrast is weak. This limits the exposure dynamic range of mammographic screen film systems to a factor of 25 – 50, which means that the image contrast in the fully glandular or fully adipose parts of the breast can be much lower than in the other areas. On the other hand, digital detectors have the significant advantage of a linear response over a wide of exposure conditions, giving constant contrast and a large dynamic range (Monnin). A mammography unit is in a shape of a box that contains a tube that houses x-rays used exclusively for breast x-ray exam.

2.4.1 Conventional or Screen Film Mammography (SFM)

The National Council on Radiation Protection and Measurements (NCRP) established guidelines that are required in using a dedicated unit when performing screen-film mammography. Although the objective of all dedicated mammography units is to produce clinically useful information on x-ray film, manufacturers may choose to engineer and design their equipments with slight differences to accommodate the unique technical demands of screen-film mammography (Andolina, Lille and Willison). The factors that influence the mammography procedure quality include the nature of the film, technology and skills used as well as the mammography knowledge, the accommodation of all patient’s ages, breast shapes and sizes. A screen film mammography uses a low dose radiographic (x-ray) film to acquire, store and display images. The transmitted x-rays are recorded in a film cassette; different parts of the body absorb and attenuate x-rays in varying degrees. Fat organs appear to pass x-rays whereas dense tissues absorb them due to their physical properties (Coiera).
2.4.2 Digital Mammography or Full-Field Digital Mammography (FFDM)

With the modern technology, the digital mystique is taking over the analog technology. While “analog” refers to the assumption of an arbitrary value, “digital (or discrete)” systems assume only few values. For the breast imaging, the transition to digital improves the quality of a mammographic image; hence, the advancement of the early detection of breast cancer. FFDM which is a new version of mammography unit is defined as “a mammography system in which the x-ray film is replaced by solid-state detectors that convert x-rays into electrical signals. These detectors are similar to those found in digital cameras. The electrical signals are used to produce images of the breast that can be seen on a computer screen or printed on special film similar to conventional mammograms” (Bassett and Gold). Digital mammography improves the signal to noise ratio and the image contrast to enable the better detection of breast cancer (Daffner).

2.4.3 Comparison between the screen-film and digital mammography

<table>
<thead>
<tr>
<th>Film</th>
<th>Digital</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latitude</td>
<td>Moderate</td>
</tr>
<tr>
<td>Display Contrast</td>
<td>Fixed</td>
</tr>
<tr>
<td>Signal to Noise Ratio (SNR)</td>
<td>Limited by film</td>
</tr>
<tr>
<td>Portability</td>
<td>Easy</td>
</tr>
<tr>
<td>Archive Security</td>
<td>Moderate-Poor</td>
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<tr>
<td>Easy of copying</td>
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<td>CAD</td>
<td>Requires digitizer</td>
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<td></td>
<td>Difficult</td>
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<td>--------------------------</td>
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</tr>
<tr>
<td>Teleradiology</td>
<td></td>
</tr>
<tr>
<td>Image Processing</td>
<td>Not possible</td>
</tr>
<tr>
<td>3-D Imaging</td>
<td>Not possible</td>
</tr>
</tbody>
</table>

Table 1: The comparison between the screen-film and digital mammography (Andolina, Lille and Willison)
Figure 6: Dedicated screen/film mammographic unit (Andolina, Lille and Willison)
2.4.4 Mammography procedure

For the best quality of images, a dedicated mammography unit is required to adequately visualize different parts of the breast in order to deeply detect tissues from which cancer can develop. The equipment should be designed in a way to provide clinically useful information about images stored on the x-ray film and acquire all the necessary special accessories to improve the exposition of the breast tissues to x-rays; those factors include but not limited to: the choice of the film, processing technique, performance, electrical requirements, density selection, source-image detector distance, voltage, current and time selections to name few. For more information about the requirements for a mammography unit to accommodate all technical demands of the screen mammography (Andolina, Lille and Willison, Chapter 5)

To perform a mammography exam, a qualified radiologic technologist positions the breast on a platform that is gradually compressed by a paddle to adjust a breast so that images can be taken at various angles; a patient might be asked to keep from breathing for few seconds to avoid blurred images and change positions slightly between images. Once the part to be examined is carefully aimed, the x-ray machine passes a small burst of radiation through the body; therefore, images are recorded on a special cassette film for film screening mammography or directly digitally to a computer for digital mammography. Once the exam is completed which takes about half an hour approximately, a patient will be required to wait for more minutes for a technologist to check if images are of high quality for a doctor to read and interpret. The patient will be notified for the results after the doctor reads and interprets the obtained images.
2.4.5 Applications of Digital Mammography

2.4.5.1 Teleradiology

Teleradiology is defined as the means of electronic sharing and transmitting radiographic images between end users; the physical location of images can be distant from the location in which images are reviewed/ read. A simplified Teleradiology system consists of the sending station where images are sent from, the receiving station where images are reviewed or manipulated for further use and the transmission network medium. The image sending interface can be a film digitizer (laser scanners, TV cameras, charged coupled scanners etc. which converts the analog film to digital format) or network interface devices (for instance a telephone modem); a modem is a device that plays a role of converting digital images into electrical impulses to facilitate the transmission over a network (Hanson III).

The transmitting network can be fiber optics (for high speed), microwave or wireline communications. The receiving station can be a modem, a hard disk drive, a TV monitor or simply a printer. Once received, radiologists manipulate images using appropriate software programs to enhance the quality for the diagnosis. Teleradiology is very useful in the areas where there is a lack of high speed internet access; the Next Generation Internet has been proposed as the appropriate way of sharing patient images at a distance to solve the problems of low speed Internet sharing. (Andolina, Lille and Willison).

2.4.5.2 Image Processing

The digital mammography for which images are stored in digital format allows the easy application of digital image processing, the core purpose of the medical imaging; in breast imaging where images are enhanced to detect and diagnose breast cancer lesions, the image
enhancement bases upon the contrast enhancement to improve the image display; for instance, peripheral equalization in which the areas under the pectoralis muscle and near the periphery of the breast are made brighter or darker to match the appearance of the tissue in the center of the breast. This enables the radiologists to review the whole breast without the manual adjustment to the viewing window or level. Another method is the image edge enhancement which consists of smoothing edges; its benefit is making small objects more visible, such as calcifications or spiculations (Andolina, Lille and Willison).

2.4.5.3 Computer-Aided Diagnosis (CAD)

In the computer-aided diagnosis systems, the image processing techniques are combined with artificial intelligence algorithms along with radiological image processing to form the Computer-Aided Diagnosis methods in which for instance tumors are detected. Radiologists use CAD to read and interpret radiographic images (Umar, Kapetanovic and Khan); the CAD system examines digitized film mammograms for evidence of suspicious masses or calcifications. Radiologists can display the findings and match with the results by scanning images (Andolina, Lille and Willison).

2.4.5.4 Three Dimensional Imaging

Medical imaging is believed to be the decent way of improving the medical image processing and interpretation. In breast imaging, the screen film mammography (2-D) is being replaced by the digital mammography (3-D breast imaging) to enhance the image manipulation and study to a better diagnosis of the breast cancer disease. (Andolina, Lille and Willison), (O'Rourke).
2.5 Breast Imaging (Migration from 2-D (mammogram) to 3-D (Digital mammogram))

Mammography continues to be the best and available tool for the early detection of breast cancer; however, mammography might fail to detect breast cancer in young women because of BReast CAncer 1 and 2 (BRCA 1 and BRCA2) which occurs at the younger age (relatively before 50). Apparently, after the age of 50, it is very easier to detect breast cancers since they appear on a mammogram as white masses associated with white calcium spots contrasted against a dark background; more importantly, women’s breast before menopause are made up with a relatively more supporting tissue (which appears “dense” or white on a mammogram) and less fatty tissue (which appears “radiolucent” or dark) (Breast Cancer). Since conventional mammography is a two dimensional (2-D) imaging modality, tissues of interest are sometime hard to analyze due to overlapping tissues below and above the lesion (Entering the Electronic Era).

Computer Assisted Diagnosis and Digital Mammography are being studied to improve the accurate interpretation of a mammography; the screen-film mammography has been improved in order to early detect various types of breast cancer to women of different ages; hence the birth to the digital mammography (3-D). Researchers believe that, a very well studied breast imaging can improve the early detection and reduce the error rate from 5% - 15% of all cases (Cahoon, Sutton and Bezdek) in addition to cost saving. In digital mammography, views of images (top to bottom and from side to side) are recorded on a high resolution x-ray digital detector which converts them into digital pictures same as those from digital camera.
3. Thesis statement & Literature Review

3.1 Thesis Statement

Breast cancer is the second cause of cancer death after lung cancer and persists to be the leading death to women in the world, in both developed and developing countries; research institutions and nonprofit organizations have been working to establish new methods and policies to improve the early detection techniques, the only key to increase the survival rate. Breast imaging, one of the medical imaging topics along with digital image processing, the soul of digital world have been found to be an accurate approach to breast cancer early detection and diagnosis. In addition to bioinformatics through Computer-Aided Diagnosis, digital mammography through either screening or diagnosis is found to be a best technique to the proper distinction between malignant and benign tissues as well as nonpalpable masses to women of various ages (Williams, Olopade and Falkson).

This research implements the DYNAMAC Algorithm, a Computer-Aided Diagnosis tool based on Dynamics Nonlinear Systems (chaotic oscillations), through the D Transform to enhance the detection of diseased tissues. Sample images were collected from Elizabeth Wende Breast Care (EWBC), the Research Department in Rochester, New York. In addition to generating a profile from diseased and healthy breast images to clearly point out non-healthy tissues, this paper aimed to suggest a telecommunication network to implement the Telehealth care to women in remote areas using Next Generation Internet (NGI) technology through Teleradiology with broadband networks. The benefit of this tool is to improve the survival rate through Teleradiology, more precisely in developing countries where there is a lack of qualified doctors and equipments with the low or absence of the high speed internet access.
3.2 Literature Review

Various studies have been done in the area of bioinformatics on cancer; the National Cancer Institute has set a priority to the development of advanced medical imaging technologies, a key role to contribute to the early detection and diagnosis. The previous work done includes but not limited to: image and signal processing using *Artificial Neural Networks* (ANN) to improve the medical image quality and analyze the survival problem. The ANN analysis shows how long the disease is expected to recur after the surgery. The ANN model is the capability to capture nonlinearities and complex interactions between factors (Fulcher). Another type of breast imaging technique is *Scintimammography* (nuclear imaging) which is implemented through a standard gamma camera to detect cancer cells to women have breast with a dense tissue. During this test, a woman receives an injection of small amount of radioactive substance called technetium 99 (Scintimammography).

Other methods of breast cancer imaging include *Thermal Infrared Imaging* (TII) in which the Infrared image (Thermal Texture Maps) provides more dynamic information of the tumor since the tumor can be small in size but can be fast growing making it appear as a high temperature spot in the IR image (Qi and Diakides). *Microwave Imaging*: a technique in which, when exposed to microwaves, breast tumors exhibits electrical properties that are different those of healthy breast tissues (Bindu, Lonappan and Thomas). *Positron Emission Tomography* (PET) scan is a nuclear medicine technique that uses a powerful camera to capture images inside the human body and shows the chemical function of the body. A PET scan reveals information about the healthy and diseased breast tissues (Guerra).
**Magnetic Resonance Imaging** (MRI): In addition to mammography, MRI is used as a supplement tool in breast cancer diagnosis. An MRI uses magnetic fields and radio waves to create images of the breast (Volakis). **Computer assisted design/Analysis software** (CAD): Computer programs that highlight suspicious areas on a mammogram to be reviewed by a Radiologist (Breast Cancer Diagnosis: CAD Technology for Mammography). **Ultrasound** (Sonomammography): Ultrasound scans are tomographic representations of breast tissue and it is used to locate a known tumor in order to guide a physician during the aspiration or biopsy procedure (Harper). Those above mentioned techniques and others not cited here have contributed to the efficient and accurate detection of breast cancer at the early stage. This paper uses a new model relying on Bioinformatics or Computer Aided Diagnosis to improve the visualization of digital images obtained from a digital mammography.
4. Approach & Methods

As mentioned earlier in the previous paragraphs, the core key role to the cure of the breast cancer disease which leads to the improved survival rate increase of the breast cancer relies only on the early detection and diagnosis of the disease before its symptoms; researchers believe that breast imaging can improve the error rate from 5% to 15% of cases (Fulcher). We approached this part basing on DYNAMAC algorithm through the D transform to compress media technologies (voice, video and images) for the ease of manipulation and networking; the D transform finds its origin in Nonlinear Dynamical Systems (Chaotic Oscillations) where it is believed that, chaotic oscillators can produce various waveform shapes to match and interpret digital sequences (Glenn, Eastman and Paliwal). One of the features of chaotic systems is their random sensitivity to the small change in the input; it is impossible to predict the output of chaos.

4.1 D-transform

4.1.1 Definition

The D-transform is a digital sequence transform used to compress digital media (images in this case) and analyze biomedical images to detect various diseases; it is a transformation and conversion from analog to Fourier; D transform finds its origin in non linear dynamical systems; “Non linear dynamics refers to the study of dynamical systems that evolve in time according to a non linear rule chaotic dynamics.” For linear dynamical systems, small changes to the input result in correspondingly small changes to the output; unlike non linear systems, this input-output proportionality does not necessarily hold; small input (caused by noise or imprecision)
might lead to large output, for instance, chaotic systems where the output is exponentially large (Ilachinski).

### 4.1.2 Concepts

The D-transform takes the advantage of the time diversity inherent in chaotic processes. The premise is this: segments of a digital sequence, such as that derived from audio, video, and image data, can be replaced by the initial conditions of a chaotic oscillation that matches it within an acceptable error tolerance. Symbolically, we can describe the D-transform operator as (Glenn, Krishnamoorthy and Mukherjee, Preliminary Development & Analysis of a New Waveform Classification Technique for Digital Signals)

\[
\tilde{d} = D(\tilde{x}, C, k) \tag{4.1.2.1}
\]

where \( x \) is the original digital sequence, \( C \) is a combined chaotic oscillation (CCO) matrix we will describe shortly, and \( k \) is the CCO matrix ordering sequence. If we call \( l(\cdot) \) a length function, then if \( l(\tilde{d}) < l(\tilde{x}) \) then compression occurs. We reproduce the digital sequence by

\[
\tilde{x}' = D^{-1}(\tilde{d}, C, \tilde{k}) \tag{4.1.2.2}
\]

The error is defined as

\[
\bar{E} = \tilde{x} - \tilde{x}' \tag{4.1.2.3}
\]

and total error over the sequence is
\[ E = \sum_{N_s} |\mathcal{E}|, \quad (4.1.2.4) \]

Where \( N_s \) is the length of the digital sequence. If \( E = 0 \), then the compression is lossless. The figure below shows a simple block diagram of the transformation and inverse transformation.

Figure 7: Block diagram of D-transform and its inverse (Glenn, Eastman and Curtis, Digital Rights Management & Streaming of Audio, Video & Image Data Using a New Dynamical Systems Based Compression Algorithm)
The following is an example of a D-Transform displaying various independent varying waveforms.

Figure 8: D transform displaying various independent waveforms (Glenn, Eastman and Curtis, Digital Rights Management & Streaming of Audio, Video & Image Data Using a New Dynamical Systems Based Compression Algorithm)

4.1. 3 Chaos Theory and Chaotic Oscillators

Mathematically, chaos is a common phenomenon that occurs in many dynamical systems; although chaos rise in purely deterministic systems, chaotic behavior predictability is impossible for long term and difficult for short term; a small change in the initial conditions will
cause a system to behave in a very different way (butterfly effect), both quantitatively and qualitatively (Zhang). Chaos find their applications in various disciplines of science; for instance, Physics, Engineering, Biology, Computer Science, Finance, Economics, Meteorology, Mathematics to name few. For a dynamical system to be classified as chaotic, it must obey three properties: exponential sensitivity associated to the input small change (initial conditions), chaotic motion being confined to a region of state space having fractal measure (strange attractor) and the ability to be synchronized with other chaotic motion. (Glenn, Krishnamoorthy and Mukherjee, Preliminary Development & Analysis of a New Waveform Classification Technique for Digital Signals).

Mathematically, broadband frequencies exist when the oscillation is chaotic; another example of the presence of a chaotic oscillator is Lyapunov exponent which is a characteristic of a separation between two close trajectories; the positive Lyapunov exponent is expressed as: (Glenn, Eastman and Paliwal, A New Digital Image Compression Algorithm Based on Nonlinear Dynamical Systems)

\[ |\tilde{d}(\tau)| = |\tilde{d}_0| e^{\lambda \tau}, \quad (4.1.3.1) \]

where \( \lambda \) is the Lyapunov exponent, \( d_0 \) is the initial separation of a set of orthogonal points in a \( N \)-dimensional space at time zero, and \( d \) is the separation of the same set of points after time \( \tau \). A typical chaotic system is the Colpitts oscillator. These sets of equations are actually derived from a standard electrical circuit architecture that is used widely in engineering (Glenn, Krishnamoorthy and Mukherjee, Preliminary Development & Analysis of a New Waveform
Classification Technique for Digital Signals). The equations are a three-dimensional set of nonlinear ordinary differential equations that have the form and the circuit diagram is:

\[ L \frac{di_L}{dt} = V_{CC} - v_c - (R + R_L)i_L \]
\[ C_e \frac{dv_e}{dt} = i_L - \frac{v_e - V_{EE}}{R_e} \]
\[ C \frac{dv_c}{dt} = C \frac{dv_e}{dt} + i_L - i_c \]

Figure 9: Circuit Diagram (Glenn, Eastman and Paliwal, A New Digital Image Compression Algorithm Based on Nonlinear Dynamical Systems)

The corresponding equations motions are as follows: (4.1.3.2) (Glenn, Eastman and Paliwal, A New Digital Image Compression Algorithm Based on Nonlinear Dynamical Systems)
where \( i_c \) is the forward transistor collector current defined by:

\[
i_c = \gamma (e^{-\alpha v_e} - 1)
\]

(4.1.3.3)

\( \gamma \) and \( \alpha \) are empirically derived factors for the transistor and \( R_L \) is the series resistance of the inductor. If we integrate these equations forward in time from a set of initial conditions

\[
[i_{i_0}, v_{e_0}, v_{c_0}]
\]

we get a set of time dependent waveforms \( i_L(t), v_e(t), v_c(t) \) that can be plotted versus time or as a state-space plot as seen in figure 9 (a), and sections of the corresponding time-dependent waveforms in figure 9 (b). (Glenn, Eastman and Paliwal, A New Digital Image Compression Algorithm Based on Nonlinear Dynamical Systems)

Figure 10 (a)
Fig 10(b)

Figure 10 (a) The three dimensional state-space plot of the solutions to the Colpitts oscillator in a chaotic regime and 10 (b) the time dependent waveforms for the inductor current, emitter voltage, and collector voltage. (Glenn, Krishnamoorthy and Mukherjee, Preliminary Development & Analysis of a New Waveform Classification Technique for Digital Signals)

4.1.4 Combined Chaotic Oscillation (CCO) Matrix

The D transform exploits the fact that chaotic oscillators are time sensitive using a series of waveforms CCO (Combined Chaotic Oscillation) matrix. The CCO matrix is a collection of digital waveforms derived from various chaotic oscillations and the combination of those waveforms in different manners. Instead of calculating the chaotic oscillations from initial conditions and mathematical expressions, the waveforms are pre-calculated and stored. This also allows greater variation in oscillation type and combination. There are thirty-two different waveforms, each comprised of $2^{16}$ data points having a 16-bit resolution. The best matching
waveform from the CCO matrix is found by a sequential search process that seeks out the
waveform with minimal error (Glenn, Eastman and Paliwal, A New Digital Image Compression
Algorithm Based on Nonlinear Dynamical Systems). The CCO matrix is a collection of time
dependant digital waveforms generated using an oscillator; the CCO is made of up to 32
combined chaotic oscillations in which a waveform is extracted in one of these oscillations by
identifying type number that ranges from 1-32, position number and a length.

1 2 3, ..., 65536

Figure 11: A CCO matrix (Glenn, Krishnamoorthy and Mukherjee, Preliminary Development &
Analysis of a New Waveform Classification Technique for Digital Signals)

K= [1, 2… 32]; There are 32! different non-repeating orderings possible. If the ordering is
changed, the image can be scrambled and K can act as a key.
4.1.5 Fourier Series Waveform Classification

Waveform families are created using Fourier Series Waveform Classification (FSWC) technique; FSWC is a procedure to optimize algorithms for naturally varying digital signals by reducing the number of iterations in order to find the optimal waveform. It is based upon the notion of the Fourier Series Decomposition of waveforms, noted as follows: (Glenn, Krishnamoorthy and Mukherjee, Preliminary Development & Analysis of a New Waveform Classification Technique for Digital Signals)

\[ v(t) = A_0 + \sum_{n=1}^{\infty} A_n \cos n \omega_1 t + B_n \sin n \omega_1 t, \quad (4.1.5.1) \]

where \( A_n \) and \( B_n \) are the Fourier coefficients for the sine-cosine form of the series. A digital sequence can be generated from the coefficients. If we designate \( M \) to be the number of bits for the quantization of each coefficient, and \( N \) to be the number of coefficients used for \( A_n \) and \( B_n \), then we designate a given encoding as \( M-N \) FSWC. Suppose we have the waveform shown in the figure below. This waveform could be pulled from the CCO matrix, or could be part of a digital audio, video, or image set of data, or any other digital sequence for that matter (Glenn, Krishnamoorthy and Mukherjee, Preliminary Development & Analysis of a New Waveform Classification Technique for Digital Signals)
Figure 12: Digital waveform used to demonstrate a 3-3 FSWC decomposition (Glenn, Krishnamoorthy and Mukherjee, Preliminary Development & Analysis of a New Waveform Classification Technique for Digital Signals)

The corresponding 3-3 FSWC decomposition is shown in fig 13 below. There are a total of six coefficients each having a 3-bit resolution, therefore resulting in an 18-bit sequence for this
waveform, that is, \( b = b_1 b_2 b_3 b_4 b_5 b_6 \). Just as the accuracy of the series increases with the number of coefficients, so does the uniqueness of the binary sequence as its length increases.

Figure 13: 3-3 FSWC sequence showing the formulation of the 18-bit sequence \( b = 100010110010010010 \). (Glenn, Krishnamoorthy and Mukherjee, Preliminary Development & Analysis of a New Waveform Classification Technique for Digital Signals)
Figure 14: shows three 128-point different waveforms extracted from a CCO matrix oscillation type number 4 (Glenn, Krishnamoorthy and Mukherjee, Preliminary Development & Analysis of a New Waveform Classification Technique for Digital Signals)
Figure 15: The FSWC decomposition of each waveform from fig. 13, and their corresponding 18-bit binary sequences. (Glenn, Krishnamoorthy and Mukherjee, Preliminary Development & Analysis of a New Waveform Classification Technique for Digital Signals)
The utilization of FSWC in reducing the search time needed to find the optimal waveform in the CCO matrix comes from the realization that sub-sequence families can be derived from the bit sequences generated. In our current example we will use 10-bit families. That is, the 10 most significant bits (msb) are used to as the search criteria. The CCO matrix can be pre-classified according to different waveform lengths such as \( N_c = 32, 64, 128, 256, \) etc., and according to the 10-bit family structure. Fig. 15 shows a histogram, or FSWC spectrum, of the number of CCO matrix waveforms that fall into the 1024 different families for \( N_c = 128 \). This spectrum indicates the total number of waveforms in a given 10-bit family that are necessary to search through in order to find the best match. In this case the maximum number of elements in a given family is 1,570, in contrast to having to search through 65,336 waveforms using the old method. In some cases, a particular family may have no members. In that case the nearest neighbor (or extended family) is used for the search criteria (Glenn, Krishnamoorthy and Mukherjee, Preliminary Development & Analysis of a New Waveform Classification Technique for Digital Signals)
Figure 16: 3-3 FSWC spectrum showing a 10-bit pre-classification family profile the CCO matrix where $N_c = 128$ (Glenn, Krishnamoorthy and Mukherjee, Preliminary Development & Analysis of a New Waveform Classification Technique for Digital Signals)
4.2. DYNAMAC Algorithm

As mentioned earlier, DYNAMAC stands for Dynamics-based Algorithmic Compression; it is a new algorithm based in nonlinear systems theory and compression tool currently used in digital media to compress images, video and speech as well analyzing medical images to identify unhealthy tissues through image extraction and segmentation. The basic foundation of DYNAMAC lies in the facts that chaotic oscillations are dynamical systems that can be controlled to generate diverse shapes of waveforms using mathematical expressions. DYNAMAC-Biomed algorithm concept lies behind the theory that binary sequences (bits 0 or 1 used to store digital information in computer) can be used to store various forms of digital media; specifically images in our research.

Moreover, these images can be represented by various shapes of waveforms generated by chaotic oscillators; the clear premise is that, an image segment of a digital sequence can be replaced by chaotic oscillator initial conditions, which in turn, matches it within a comparable error tolerance; if the image size needed to identify conditions required to generate a chaotic oscillator is less than the digital sequence size, then the compression is achieved. Below is the block diagram of a DYNAMAC algorithm:
Figure 17: DYNAMAC Algorithm block diagram (Glenn, Eastman and Paliwal, A New Digital Image Compression Algorithm Based on Nonlinear Dynamical Systems)

DYNAMAC Algorithm divides a bitmap image into digital sequence; then it looks inside the combined chaotic oscillator matrix (CCO) a waveform that can closely match the assigned digital sequence; waveforms are identified as 40-bit sequence or D-bite inside a CCO matrix. A D-bite consists of three types of digital sequence that correspond to three color space: Red (R), Green (G) and Blue (B); each color has its own D-bite which gives the following order: $D = \{D_1, D_2, D_3\}$, each segment's size will be 108 bits. In order to access to waveforms inside the CCO matrix, an ordering key is required whose index is a part of the D-bite; that is how the algorithm embeds the digital rights managements. However, if the wrong key is pressed in the decoding process, the produced (decompressed) image will look scramble or fuzzy.
4.3 Image collection

Images used in this research work were extensively collected from the Elizabeth Wende Breast Care, in the Research Department, Rochester, New York, United states; those images were handed out in DICOM (Digital Imaging and Communications in Medicine) format on a hard drive memory along with reports of patients with anonymous names. We used a software algorithm called ezDICOM to display those X-ray images which helped us to save them into 24-bitmap format that is compatible with the DYNAMAC-Biomed Algorithm (specific to biomedical images). About 150 x-ray mammography images were collected in which 41 best and clear diseased samples were processed to generate the average cancer profile; the generated cancer profile was used to compare the rest of the images to study and identify diseased tissues from the healthy ones.

4.4. Image Processing

During the procedure, the bitmap images have been processed and scanned to create the average profile; the obtained profile was stored from both 41 diseased and 40 healthy image samples. During the scanning process, the DYNAMAC algorithm scans the entire CCO matrix mentioned earlier to search the appropriate waveform that best match the digital sequence segmented from the breast image; the procedure of this phenomenon is that, the parts of the image that are prone to the disease (abnormalities) are isolated and compressed separately. Then the CCO identifies them as waveforms in D-bites unit, the compression process is achieved by using FSWC technique; hence, there will be a number of types of waveforms used for that particular compression process that belong to a specific family of waveforms in the CCO and then the classification is stored.
On the other hand, if the there are previously stored images identified as diseased (the average cancer profile outcome), then the algorithm will compare the current classification to the pre-compressed and stored images to give out a level of difference between the two results using a waveform level comparison scheme (error difference). Therefore, this will conclude to decide on breast tissues that are healthy and identify the diseased one, which is the core part and purpose of this work study. The attached spread sheets and tables indicate the error difference to isolate healthy tissues from unhealthy ones; the GUI (Graphic User Interface) that is used to display the process looks as follows:

Figure 18: Image extraction and processing
The above figure displays a bitmap image, one primary segment extracted and the corresponding histogram; the process consists of dividing the image into various segments using the primary segment position. The above displayed image segment is extracted from a diseased breast image basing on cancerous tumors properties which includes but not limited to the fact that breast masses appear on a mammogram as white masses associated with white calcium spots contrasted against a dark background. The scanning process has been done on 41 different image samples; each tissue profile was stored to be used to generate the overall average profile.

Figure 19: Histogram comparison: a diseased tissue against the cancer average profile

In the above figure, the previously stored average profile analyzed from 41 diseased images has been previously stored to be compared to a segment extracted from a random breast
image; the displayed histogram for both shows that some segments and tissues have the error nearly or equal to zero; segment 1, 2 and 4 display the likeness to the cancer average profile which means they are likely to be cancerous tumors. The process was repeated for several images; hence, the purpose of this research work was achieved through verifying that, the previously stored cancer profile has been a bottom line to measure the degree of wellness in the future implementation to other breast images.

Figure 20: Health and Diseased Image Comparison

From the figure above, two image segments were compared against each other, the first is a diseased breast tissue sample and the second is a healthy breast tissue. The histogram
displayed by a segment extracted from a diseased tissue shows more number of histograms whereas the second (the healthy one) shows less number of histograms.

Figure 21: A diseased tissue compared with another segment of the same image

From the above comparison, there is a slight difference between these two tissue profiles, which means the second one, which might mean that the rest of the image is likely to be infected as well; this means that cancer has spread around.
Figure 22: The comparison between two segments from two different images

The comparison shows a neat difference between the displayed profiles; the first displays a mass while the second is extracted from a healthy image. More samples were shown using the GUIs in the previous pages.
Figure 23. The image loading and the segment scanning process

From the above GUI, the image is segmented into 2 boxes where both of them are scanned and compared to the previously stored profile. The error difference is shown above which leaves the first box equal to the zero line. This is to prove that the first segment is a breast mass.
Figure 24: The Error difference association to the image segment

The box 2 extraction and the corresponding error difference are displayed above. The loaded average profile on the top right is the previously stored average cancer profile. The figure above shows that the circled box 2 is likely to be cancer; the corresponding error difference which nearly close to 0 proves the extracted tissue has a cancerous tumor.
Figure 25: The average Cancer Profile

This displayed profile is a result of 41 unhealthy breast images scanned and processed using the DYNAMAC-Biomed Algorithm software as shown in the previous pages.
Figure 26: The Average Healthy profile

The displayed profile is a result of 40 breast healthy tissues scanned and processed using the DYNAMAC-Biomed Algorithm tool using the model in the previous pages.
5. Results analysis

Details of healthy and diseased tissues were analyzed and interpreted in the above pictured figures; the DYNAMAC-Biomed algorithm explained in detail in the previous paragraphs has been a successful tool to identify and early detect diseased tissues. Initially, diseased and healthy breast images are known and identified, which helped us to analyze the average profile. This average profile was stored for the purpose of studying tissues segmented from other images that were not pointed out to be cancerous tumors. From the results, scanned images showed the likeness between their profiles and the average profile. The details of images and the error difference are shown in two tables below; in table 1, several diseased breast images are compared to healthy and cancer average cancer profiles to test the likeness and the difference, their format and source are also mentioned in the paper; similarly, table 2 shows healthy images compared against both healthy and cancer average profiles.

In previous research, we have tested the DYNAMAC algorithm accuracy to lung cancer images which turned out to be successful; we have been trying to implement the same tool to various biomedical images which is now successful. DYNAMAC algorithm can identify diseased tissues by using the comparison of the image digital sequences to the corresponding waveforms inside the CCO matrix performed by the FSWC technique. With this tool, we are able to provide the Telehealth care to women with identified diseased tissues using Telemedicine and Teleradiology.
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Table 2: diseased tissues
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Table 3: Healthy tissues
6. Applications: Telemedicine

6.1 Definitions

Telemedicine is “a delivery of health care from a distance using electronic information and technology such as computers, camera, videoconferencing, internet, satellite and wireless communications” (National Cancer Institute, Telemedicine); it is also defined as “a process that assist with health care service that employ communications services and equipment. Examples of telemedicine include delivery of medical images, remote access to medical records, remote monitoring of health care equipment and distant monitoring of biological functions such as heart rate and blood pressure.” [Online Communication Dictionary, Telemedicine].

Telemedicine is the provision of healthcare services, clinical information and education over a distance using Telecommunication Technology- existed long before the Internet. (Maheu, Whitten and Allen).

Telehealth is “the integration of telecommunication systems into the practice of protecting and promoting health, while telemedicine is the incorporation of these systems into curative medicine (Telehealth); E-health is a reflective of a sea change: the movement from innovative health care delivery through independent telemedicine and Telehealth projects to the worldwide distribution network known as the Internet. E-health refers to all forms of electronic health care delivered over the Internet, ranging from informational, educational and commercial products to direct services offered by professionals, nonprofessionals, businesses or consumers themselves”. (Maheu, Whitten and Allen)
6.2 History

Though Telemedicine is sometime thought to be a recent and brand new idea, Telehealth care industry dates back in 1900s in the era of pre-television; the following is the brief chart of the telemedicine history (Maheu, Whitten and Allen)

Early 1900: Radio communications used to provide medical services in Antarctica

1910: The attempt of using the radio tele-cardiology

1920: The use of the first transtelephonic (telephone mediated) “electrical stethoscope”

1950: The first radiological images transfer and video phone experiments; in late 1950, it occurred the first use of interactive video communications in health care when the Nebraska Psychiatric Institute (Dr Cecil Wittson’s microwave-mediated rural telepsychiatry, Omaha, NE, US) used a two way interactive television system for telepsychiatry consultations with Dr Albert Jutras’s cable mediated Teleradiology in Montreal, Canada

Later on, the National Aeronautics and Space Administration (NASA) invested in the early development of Telemedicine; NASA supported the establishment of a comprehensive test bed system known as STARPAHC (Space Technology Applied to Rural Papago Health Care) in Tohono Odham (formerly Papago), Arizona. For a period of 20 years, the program tested satellite-based communications designed to provide both the reservation and astronauts with a wide range of medical services (Fuchs, 1979). Meanwhile, NASA continually sponsored in maintaining the disaster assistance, Space Bridge (1988) etc.
In 1985, the SatelLife/HealthNet program began to provide health communications information and services in developing countries by linking remote clinics to urban medical centers in nine African countries, the Philippines and three South American countries (Ferguson, Doarn & Scott, 1995).

The beginning of 1990 remarked the renaissance of Telemedicine in the US, because of political changes, there was a significant increase in federal funding of rural telemedicine projects. Similarly, advances in image digitization and data compression technology were introduced, which enabled the interactive video-conferencing over lower bandwidth lines. Later in 1993, there were 10 telemedicine programs using interactive video conferencing technology in the United States. As of 1999, there were in excess of 170 interactive video-Telehealth programs in the United States alone (Grigsby & Brown, 2000).

6.3 Introduction

Telemedicine is a broad term to describe the health care provided when a distance separates participants, it is a rapidly growing part of the medical information management market; it is also one of the largest and fastest growing segments of the hearth care device industry (Harte, Levine and Kikta); it is in the same context this research work relies in the Internet and Telecommunication technologies to provide a remote care to isolated communities. Women living in rural areas struggle to get a timely access and quality medical care; the breast cancer death rate and other types of cancer can only dramatically decrease by the early detection and diagnosis in addition to contribute to the successful cure of the disease. The type of the Telemedicine applied in this paper is Teleradiology, which is a process of sending and sharing radiological images for instance x-ray in this case (Coiera).
6.4 Technologies

Telemedicine is practiced through two types of communications: store-and-forward (asynchronous communication) or real times (synchronous communication) which are both mentioned in this research paper.

6.4.1 Synchronous services (*Real time technology or simply “alive”*)

“Data, video and audio synchronous files transmissions are available almost immediately; it allows simultaneous interactions (review and discussion of files, situation or a condition of a patient). Examples include a standard phone conversation or interactive video-consultation or interactive televideoconferencing (ITV) from a specialist in the urban area to a patient in remote area. The advantage of ITV is that the specialist can directly interview and examine a patient. Real time technology is appropriate and useful in areas that require extensive and accurate interaction between a patient and a specialist.

6.4.2 Asynchronous services (*Store and Forward Technology*)

Asynchronous services are achieved through store-and-forward (S&F) technology. This technology offers more flexibility since it does not require both parties (the sending and the receiving ends) to be simultaneously present for the treatment; the disadvantage of this technique is when the sender needs an immediate reply or to schedule a live consultation or a meeting. Examples of S&F technique is the standard e-mail correspondence, teleradiological images transmission, materials needed for distance learning in tele-education etc.
6.5 Transmission channels

To achieve an accurate service, the transmission and delivery of information play a big role in our daily life; for a better output, the input and the transmission means should be accurate and appropriate. Similarly, in order to fully benefit from the telemedicine technology, several techniques have to be investigated at their fullest. As mentioned in previous lines, Telemedicine is a combination of both telecommunication technologies and medicine; transmission means can be either dial up (On-demand services: Standard telephone, ISDN, cellular telephones and some satellite services) or dedicated connections (Permanent services:
DSLs, Leased Lines, cable, microwave links and satellite). The user has to choose first which transmission channel to use depending on the nature of files to be shared; below are various techniques applied in Telemedicine: ISDN (Integrated Service Digital Network) which replaced conventional PSTN (Public Service Telephone Network) technology, ATM (Asynchronous Transfer Mode), Ethernet Networks, Frame Relay, DSL (Digital Subscriber Line), Optical Network Solutions, Cellular, Wireless, Satellite and Next Generation Networks.

6.5.1 ISDN

ISDN is a circuit switched network and a technology that provides services (Voice, video and data) using ordinary copper wire telephone lines; it is broadly used in videoconferencing where individual remote desktops videoconferencing systems are linked to share video, voice and text transmissions. Several types of ISDN are Primary Rate ISDN (PRI), Basic Rate ISDN (BRI) and Broadband ISDN (B-ISDN); the ISDN configurations enable telemedicine consultations, tele-education and other related applications.
6.5.2 ATM (Asynchronous Transfer Mode)

ATM is a packet-switched technology and data encoding type; ATM operates in higher bandwidth with a considerable low delay and it is a multiplexing technology which finds its primary use in backbone networks; for instance, backbones for ISP (Internet Service Providers) to provide P2P (point-to-point) & P2MP (point-to-multipoint) video connections (Perros). ATM works by dividing packets into standard 53 fixed cells before their transmission; “ATM networks in Telemedicine support a broad range of configurations for interlinking such sites as hospitals, healthcare clinics, medical offices, and nursing homes. These networks also enable healthcare services in a patient's home in the event of budget cuts and hospital closures and provision access to diverse treatment options for patients at distant locations” (Littman).
6.5.3 Ethernet Networks

Ethernet technology is an IEEE 802.3 standard developed by Xerox back in 1973-1975; Ethernet network is a LAN or Wireless LAN (Local Area Network) that uses different types of topology (bus or star) to connect various nodes in a network; nodes compete to get access to the cable using Carrier Sense Multiple Access with Collision Detection (CSMA/CD) technique. Ethernet belongs to both the Physical and Data Link layers of the OSI model; Ethernet application in Telemedicine includes the FDDI backbone that interworks with Ethernet and Fast Ethernet segments to support IP Multicast to access to patient records in the St John’s Hospital, affiliated with Southern Illinois University School of Medicine (Littman) and many more.

![Figure 29: An Ethernet/Fast Ethernet LAN configuration (Littman)](image)

6.5.4 Optical Networks

Fiber Optic Communication is a method of delivering and carrying information (data, video and audio) by transmitting light through an optical fiber; which gives the advantage of
enabling high speed transmission of Internet Communication, telephone & CATV signals in addition to high bandwidth. Fiber Optic is widely used to connect longer distances switches, Central Offices and Single Loop Carriers for Telecom Companies; LAN primarily uses fiber in the backbone which extends it for longer distances. One of live applications of optical network is “the High-Speed Connectivity Consortium (HSCC) that supports implementation of a nationwide multigigabit WDM network testbed that supports voice, video, and data transmission at 2.488 Gbps (OC-48). This all-optical network provisions advanced services with QoS assurances and supports applications that include data mining, electronic commerce (E-commerce), telemedicine, distance learning, video telephony, and collaborative teleworking. The University of Washington, Carnegie Mellon University (CMU), Qwest Communications, and Ciena Corporation participate in the HSCC testbed project” (Littman)

6.5.5 Frame Relay & Fibre Channel technologies

Frame Relay is a high-performance WAN protocol that operates at the physical and data link layers of the OSI reference model. Frame Relay originally was designed for use across Integrated Services Digital Network (ISDN) interfaces (Cisco: Frame Relay); it is a networking solution that provides connectivity and communication between multiple locations supporting a variety of applications (Henderson and Jenkins). Fibre Channel (FC) technology is designed for high performance low-latency data transfer among various types of devices; FC is mainly used in the implementation of Storage Area networks (SAN) (Fibre Chanel). The live application is the telemedicine initiative of the US government where the “Veterans Health Administration (VHA), an agency of the U.S. Department of Veteran Affairs (VA), supports utilization of a Frame Relay network that operates over fiber optic cabling for linking more than 600 VA
facilities nationwide. The Frame Relay configuration enables these VA facilities to exchange data with medical centers, regional offices, and the VA Central Office” (Littman)

6.5.6. Digital Subscriber Line (DSL)

DSL is a cheap service and a way of communicating at high speed than that of a modem using wires similar to standard telephone line. DSL technologies “support links to a broad spectrum of Web portals and Internet services and applications such as e-mail exchange, IP telephony, and television programming. In addition, DSL is an enabler of tele-education, teleshopping, E-banking, teletraining, VPNs (Virtual Private Networks), video gaming, teleworking, telementoring, tele-entertainment, and telemedicine” (Littman)

6.5.7. Wireless Networks

A wireless network refers to any type of computer interconnection in which there is no presence of wires; for instance, LAN, WAN, MAN and others. Enabled by wireless networks, information can be reliably and efficiently transmitted overseas; for instance, cellular telephones (GSM & CDMA), internet etc. A live application of wireless networks in Telemedicine is that “Physicians at Good Samaritan Hospital, Ohio, employ a broadband FWA Ethernet LAN for accessing records of patients in cardiac and surgical units, intensive care recovery rooms, a birthing center, and hospital clinics. In addition, physicians also monitor patient medications, access intake orders, and review treatment protocols in real-time at the patient's bedside via the WLAN solution” (Littman)
6.5.8 Satellite Networks

“Satellite systems employ radio waves in the super-high and extremely high RF (radio frequency) bands of the electromagnetic spectrum to enable dependable transport of voice, video, data, and still images. Satellite configurations utilize state-of-the-art technologies for facilitating high-speed access to bandwidth-intensive resources and time-critical data. Rapidly evolving satellite networks are further distinguished by their provision of on-demand seamless mobile communication services at anytime and in every place and delivery of broadband multimedia applications to subscribers at rural locations. One of its applications is in Telemedicine in which Sponsored by the U.S. Department of Defense, the Telemedicine and Advanced Technology Research Center (TATRC) provisions access to programs in telehealthcare, telemedicine, and medical informatics. TATRC also employs satellite services to support delivery of telemedicine treatment to U.S. military forces in Iraq, Somalia, Rwanda, Croatia, Macedonia, Haiti, Panama, Cuba, Egypt, Russia, Sweden, Kenya, and the United Kingdom” (Littman)

6.5.9 Next Generation Networks (NGN)

Next Generation Networks (NGN) is a broad term to refer the new telecommunication technology evolutions to be deployed over next 10 years. Next Generation network is an IP based network in which service related functions are separated from transport related functions; in simplest terms, NGN is the packet network that converges the public switched telephone network, the data network (the Internet), and the wireless network NGN can be deployed using
various network devices; for instance, Softswitch, Media Gateways, Routers etc. (*NGN Design & Implementation, Principles of Telecom & Networks, Alphonsine Imaniraguha*).

NGN promotes the Next Generation Internet (NGI) through connecting schools, hospitals and research centers across the United States at high speeds rate; one of the NGI initiative is the University of Iowa National Laboratory for the Study of Rural Telemedicine that evaluates capabilities of videoconferencing teleconsultations over the NGI between healthcare specialists and patients with special needs, including children with heart conditions or disabilities and persons with mental illness. In addition, the merits of delivering healthcare information to television sets equipped with special devices in the homes of patients with diabetes for enabling these patients to effectively manage their disease are explored” (Littman)

**6.6 Equipment**

With the tremendous growth of the Internet technology and the availability of low cost personal computers (PCs) within the past few years, everything is going over Internet Protocol (EoIP). Telemedicine technology has quickly and noticeably changed and improved over the past decade; with the previous mentioned examples of transmission channels, this research work consisted of suggesting a Telecommunication network link design that can be implemented to promote the Telehealth care in rural and remote areas of Rwanda. The Information Technology (IT) is used to increase the efficiency of the Telehealth technology and reach out patients; this will eliminate distance barrier between caregivers and patients. Below is a sample schematic diagram of tele-intensive care between hospitals.
In our network design, we have 3 sites as shown by the figure 31 below: URMC (University of Rochester Medical Center), NURMC (National University of Rwanda Medical Center) & Ndera Breast Care (NBC). Services between these hospitals will include consultation,
diagnostic, transfer of patient related records using “store-&-forward” technology through Teleradiology. In this type of technology, images will be acquired at one location (NBC for instance) and stored, then forwarded to the NURMC (National University of Rwanda Medical Center) for the monitoring, analysis and interpretation. The DYNAMAC algorithm will be installed in PCs to enable and facilitate the transmission, sharing and manipulating breast radiological images through the compression tool in order to save the operational bandwidth and QoS requirements.
Figure 31: A map showing three sites: URMC, NURMC & NBC

The core network comprises of high speed routers to serve and share medical information among medical document servers and the centralized database; the access network consists of
VSAT dishes at each location to relay data from the Kicukiro earth station to URMC, NURMC and NBC. The equipment at the end users consist of PCs connected to a broadband network; the remote doctor equipments consist of PCs, which are connected through a reliable, on demand and high speed network to efficiently handle large files to ensure an accurate diagnosis. The DYNAMAC-Biomed software tool will be configured and installed in the PCs for the image monitoring and diagnosis; the high speed network suitable for the ultimate telemedicine technology will be achieved through satellite and terrestrial links, ISDNs, ATM and LANs.

6.7 Implementation

In this paper, the telemedicine implementation through Teleradiology between the two sites in Rwanda is accomplished in a case study: suggest a network design that will serve small breast clinics in rural areas of the Eastern Province of Rwanda from the National University of Rwanda Medical Center (NURMC), Butare and Kigali, Rwanda, East Africa. This network will serve women patients in most areas of Kigali and Butare; the NURMC will in turn work and share data with the University of Rochester Medical Center (URMC), Rochester, New York, United States through the high speed Internet (Satellite Communications) enabled by the Next Generation Networks technology through both real time (synchronous) and store-and-forward (asynchronous) techniques for further diagnosis.
7. Conclusion & Future Work Recommendations

7.1 Conclusion and Summary

With the modern technology and availability of research centers, the breast cancer disease continues to be a global issue in the women’s lives in both developed and developing world; while the clear cause of the disease remains unknown, the only factor remains of undisputed: the early detection and the diagnosis of the disease before its symptoms. Researchers believe that Medical Imaging saves many lives; medical imaging is the process and techniques to manipulate the human body images for clinical investigations. It is a way of assisting with finding the breast cancer early when it is still treatable and diagnosable. The early detection and the appropriate diagnosis of the breast cancer contribute to the successful cure of the disease. With the digital world, this paper suggested the Digital Mammography in which breast images are recorded on a high resolution x-ray digital detector which converts them into digital pictures same as those from digital camera. Mammography plays a big role in detecting breast cancer for that it is capable of showing breast changes up to 2 of years before the tumors are palpable.

The obtained images are further manipulated by radiologists using the Computer-Aided Diagnosis to process breast images; in this paper we implemented the DYNAMAC-Biomed image compression software tool which has its origin in Non Linear Dynamical Systems. The goal of this tool is to eventually help analyzing the average profile obtained from 41 different breast diseased images which are processed and scanned to detect cancerous tumors; after the identification of the tumors which was derived from processing each image separately using image segmentation and comparing the histograms, we worked to establish a health care to women in rural areas of Rwanda, East Africa. Using the modern telecommunications
equipments and the next generation broadband networks, women in those remote areas will receive the appropriate treatment and diagnosis of the disease through mainly Teleradiology. This will eliminate the need of traveling many miles of patients and high rate pay of doctors and specialists on remote sites.

The radiological images will be transmitted back and forth between the NURMC and URMC back to NBC. The successful cure of the disease is achieved using qualified staff and doctors from the URMC, United States who will examine and work with the radiologists at the National University of Rwanda Medical Center, Butare, Rwanda. The nature of work includes sharing breast images, patient consultation, images manipulation etc through mainly store-and-forward communication. The DYNAMAC tool is beneficial basing on the fact that, it is easily implemented and explored; moreover, it meets the requirements of Medical Imaging and Breast Imaging in particular by including the detailed study of breast tissues to identify the infected areas of the image. The work had run successful and this paper includes a compiled result tables that shows the similarity and the difference as well as properties of diseased and healthy tissues.

7.2 Future work

This paper suggests the deployment of a network that will deliver the breast health care between remote sites and hosts, the collaboration between three sites: National University of Rwanda Medical Center, Ndera Breast Care and the University of Rochester Medical Center; the nature of the health care delivery consists of the patient consultation and discussion of their needs, sharing patient’s records using high bandwidth telecommunication infrastructure. For the future work to enhance the breast care in the developing world, further steps should be taken to extend this project to a live implementation; this means to consult the remote sites for a neat
project plan that would estimate costs and acute equipments needed for the implementation. The cost would depend on various factors that include the nature of the sites, the population, the geographical locations, the patient needs to name few.

Future work also should be done to enhance the improvement of the processing (compression/decompression) time of the DYNAMAC tool and the image quality to minimize the errors that can occur during the process. Also, DYNAMAC-Biomed was applied to early detect lung cancerous tumors from several lung cancer image samples; this project had positive outcomes which made us to apply the same practice to breast images part of the breast imaging. Taking into account that lung and breast diseases are not the only cancers frequent in the human race, future work should apply same concept to other types of cancers; for instance, ovarian and cervical cancers to name few.
8. List of reference


Abnormalities of the female breast.  


"Breast Cancer Diagnosis: CAD Technology for Mammography." Imaginis Website.  


9. Appendix

Below is the list of few of the diseased and healthy images that are used in this paper. White areas are masses.

Breast cancer image, EWBC, Rochester, New York, 2008
Diseased image 4, EWBC, Rochester, New York, 2008
Diseased Image 5, EWBC, Rochester, New York, 2008
Diseased image 6, EWBC, Rochester, New York, 2008
Diseased image 7, EWBC, Rochester, New York, 2008
Diseased breast image 8, EWBC, Rochester, New York, 2007
Diseased breast image 9, Rochester, New York, 2008
Normal breast image 1 (EWBC, Rochester, New York, 2008)
Normal breast image 2 (EWBC, Rochester, New York, 2008)