CHAPTER 1
INTRODUCTION

1.1 PROBLEM FORMULATION

A medical survey reports that in recent days 20-25% of the women are affected by uterine fibroid. Uterine fibroid is the most common benign tumor of the female in the world. An ultrasound image of fibroid has been found as one of the reliable imaging techniques for early detection of tumor and its characteristics. The most noticeable advantages of ultrasound scanning are safety, cost effectiveness, speed, easy handling and portability.

The development of Computer Aided Diagnosis System has been focused by many researchers for providing valuable information to the radiologists. Early detection of uterine fibroid can play an important role in reducing the associated morbidity rates.

In the development of automated uterine fibroid classification system, the analysis of tumor detection depends on the regions of interest, which are usually of low contrast and noisy nature (speckle noise). Speckle noise is a multiplicative noise. Hence an image de-noising and enhancement may be required to preserve the image quality, to highlight image features and to suppress the noise.

Earlier non linear filters have been used for enhancing the tumor area in the image. The median filter introduces noise into the transformed image. This noise levels can generate streaks and amorphous blocks in the image. In order to overcome the above limitations, in the present work
Wavelet transform with Haar function has been used for preprocessing. This is applied to remove the noisy fluctuations and also to enhance edges which contain semantically useful information. The shape, boundary and intensity variation of abnormal regions are found to be the most important features in tumor detection. The segmentation is to distinguish one or more regions of interest (ROIs) from the selected image after pre-processing.

In this research a CAD system has been developed and the performance has been estimated. The image enhancement, de-noising, extraction of multiple feature set with multi objective genetic algorithm, classification using Multilayer Back Propagation Neural Network with Ant Colony optimization considering particle swarm optimization has been used to identify the CAD system. The CAD system is used to identify the fibroid for further pathology.

1.2 OBJECTIVES

The objectives of the present work are:

- To extract shape and texture features from ultrasound uterine fibroid image after preprocessing.
- To obtain the optimized feature set using Multiobjective genetic algorithm.
- To implement a CAD system for analyzing and classifying the types.
- To identify the stages of fibroid
- To estimate the performance of the classification algorithm.
1.3 BACKGROUND

1.3.1 Uterus

The uterus is a powerful muscle located in lower pelvis. It is also called womb, a major female hormone-responsive reproductive sex organ of most mammals including humans. One of the main functions of the uterus and ovaries, are cardiovascular protection. When the uterus is removed, the women have three times greater incidence of heart diseases. So this organ is needed to protect from their abnormalities. In recent days, above 40 year women’s are affected by the uterine fibroid. The exact development of fibroid merely depends on the presence of hormones such as estrogen, progesterone and possibly other. Some of the fibroid are cured by giving medicine or by surgery.

![Uterus Image](Image)

**Figure 1.1 Uterus Image**

The female reproductive organs include,

- The Vagina
- The uterus
The female reproductive organs are located in the pelvis, between the urinary bladder and the rectum.

The ovaries have two main functions.

1. The production of specialized hormones, such as estrogen and progesterone
2. Ovulation, which is the release of eggs that are needed for reproduction.

The hormones produced by the ovaries are very important in keeping ovulation regular. These hormones also prepare the inner lining of the uterus to proceed with a pregnancy. When an egg is released, it goes down to the uterus through the fallopian tube, where it may be fertilized. If the egg is not fertilized, the egg and the inner lining of the uterus are discharged to the outside of the body during the menstrual period.

The uterus is pear shaped. It is about three inches long and has three layers. The inner layer of the uterus is called the endometrioses. As menopause approaches, periods become irregular and eventually stop. Menopause occurs when the ovaries quit making hormones and releasing eggs.

When a woman gets pregnant, the fetus stays in the uterus. The uterus is able to expand greatly in size. The middle, muscular layer of the uterus creates labor contractions, which cause the baby to come out.
The lower part of the uterus is called the cervix, which opens into the vagina. The vagina opens to the outside of the body between the urethra, which is the urinary bladder opening, and the rectum. The urinary bladder is located in front of the ureters. The intestines and the rectum are located behind the vagina and uterus.

Parts

The uterus has three parts:

- **Top**: The top (fundus) of uterus is shaped like a dome. From the top of uterus, the fallopian tubes extend to the ovaries.
- **Middle**: The middle part of uterus is the body (corpus). This is where a baby grows.
- **Bottom**: The narrow, lower part of uterus is the cervix. The cervix is a passageway to the vagina.

Layers

The layers, from innermost to outermost, are as follows:

Endometrium

The lining of the uterine cavity is called the "endometrium". It consists of the functional endometrium and the basal endometrium from which the former arises. Damage to the basal endometrium results in adhesion formation and/or fibrosis (Asherman's syndrome). Depending on the species and attributes of physical and psychological health, weight, environmental factors of circadian rhythm, photoperiodism, the effect of menstrual cycles to the reproductive function of the uterus is subject to hormone production, cell regeneration and other biological activities.
**Myometrium**

The uterus mostly consists of smooth muscle, known as "myometrium." The innermost layer of myometrium is known as the junctional zone, which becomes thickened in adenomyosis.

**Parametrium**

The loose connective tissue around the uterus.

**Perimetrium**

The peritoneum covering of the fundus and ventral and dorsal aspects of the uterus.

**Uterine Abnormalities**

All uterine abnormalities do not prevent a woman from getting pregnant, but they may make it more difficult for her to carry a baby for the full nine months of pregnancy. The main abnormalities of the uterus are

- Polyps
- Scattering of the uterine cavity
- Separate uterus
- Bicomuate uterus
- Unicomuate uterus
- Adenomyosis
- Fibroids
Fibroids are the most common benign tumors in females and typically found during the middle and later reproductive years. While most fibroids are asymptomatic, they can grow and cause heavy symptoms.

1.3.2 Uterine Fibroid

A uterine fibroid is the most common benign tumor of a woman's uterus (womb). Fibroids are tumors of the smooth muscle that is normally found in the wall of the uterus. They can develop within the uterine wall itself or attach to it. They may grow as a single tumor or in clusters. Uterine fibroids can cause excessive menstrual bleeding, pelvic pain, and frequent urination, so even though they are termed "benign tumors," fibroids potentially can cause many health problems.

Uterine fibroid types

Fibroids are classified by their location (Figure 1.2), which effects the symptoms they may cause and how they can be treated.

![Fibroid Uterus](image)

**Figure 1.2 Uterine Fibroid locations**
- **Intramural Fibroids** are located within the wall of the uterus and are the most common type, unless large, they may be asymptomatic. Intramural fibroids begin as small nodules in the muscular wall of the uterus. With time, intramural fibroids may expand inwards, causing distortion and elongation of the uterine cavity.

- **Subserosal fibroids** are located underneath the mucosal (peritoneal) surface of the uterus and can become very large. They can also grow out in a papillary manner to become **pedunculated fibroids**. These pedunculated growths can actually detach from the uterus to become a parasitic leiomyoma.

- **Submucosal fibroids** are located in the muscle beneath the endometrium of the uterus and distort the uterine cavity, even small lesion in this location may lead to bleeding and infertility. A pedunculated lesion within the cavity is termed an **intracavitary fibroid** and can be passed through the cervix.

- **Cervical fibroids** are located in the wall of the cervix (neck of the uterus). Rarely fibroids are found in the supporting structures (round ligament, broad ligament, or uterosacral ligament) of the uterus that also contain smooth muscle tissue.

Fibroids may be single or multiple. Most fibroids start in an intramural location that is the layer of the muscle of the uterus. With further growth, some lesions may develop towards the outside of the uterus or towards the internal cavity. Secondary changes that may develop within fibroids are hemorrhage, necrosis, calcification, and cystic changes.
Uterine Fibroid Causes

The exact reasons why some women develop fibroids are unknown. Fibroids tend to run in families, and affected women often have a family history of fibroids. Women of African descent are two to three times more likely to develop fibroids than women of other races. Fibroids grow in response to stimulation by the hormone estrogen, produced naturally in the body. These growths can show up as early as age 20 and shrink after menopause when the body stops producing large amounts of estrogen. Fibroids can be tiny and cause no problems, but they also can grow to weigh several pounds. Fibroids grow slowly.

There are factors that can increase a woman's risk of developing fibroids.

- **Age** Fibroids become more common as women age, especially during the 30s and 40s through menopause. After menopause, fibroids usually shrink.

- **Family history.** Having a family member with fibroids increases risk. If a woman’s mother had fibroids, her risk of having them is about three times higher than average.

- **Ethnic origin.** African-American women are more likely to develop fibroids than white women.

- **Obesity.** Women who are overweight are at higher risk for fibroids. For very heavy women, the risk is two to three times greater than average.

- **Eating habits.** Eating a lot of red meat (e.g., beef) and ham is linked with a higher risk of fibroids. Eating plenty of green vegetables seems to protect women from developing fibroids.
Foods to Avoid With Fibroids on the Uterus

Foods high in saturated fats should not be consumed by fibroid patients. These fats can raise the estrogen level, which allows fibroids to grow larger. Avoid bacon, sausage, egg yolks, avocados and high-fat processed snacks such as cookies and pastries, which are loaded with saturated fats. Red meat from mammals and duck are not recommended for those with fibroids. Women with fibroid tumors are encouraged to limit consumption of high-fat dairy products such as whole milk, cream and butter. These products are often high in added hormones. According to Healthy net, these foods alter estrogen metabolism and can cause fibroids to grow larger. These foods include pasta, white bread, white rice, cakes and cookies.

The following factors have been associated with the presence of fibroids:

- Being overweight, obesity
- Never having given birth to a child (null parity)
- Onset of the menstrual period prior to age 10

Symptoms

Most fibroids, even large ones, produce no symptoms. However, when women do experience symptoms, the most common are the following:

- heavy bleeding (which can be heavy enough to cause anemia) or painful periods
- feeling of fullness in the pelvic area (lower stomach area)
- enlargement of the lower abdomen
- frequent urination
- pain during sex
- lower back pain
- complications during pregnancy and labor, including a six-time greater risk of cesarean section
- reproductive problems, such as infertility, which is very rare
- Irregular vaginal bleeding
- Pressure on the bladder, which may cause frequent urination
- Pressure on the rectum, resulting in constipation
- Pelvic pressure, "feeling full" in the lower abdomen, lower abdominal pain, increase in size around the waist and change in abdominal contour

**Diagnosis**

While a bimanual examination typically can identify the presence of larger fibroids, ultrasonography (ultrasound) has evolved as the standard tool to evaluate the uterus for fibroids. Sonography will depict the fibroids as focal masses with a heterogeneous texture, which usually cause shadowing of the ultrasound beam.

The location can be determined and dimensions of the lesion measured. Also magnetic resonance imaging (MRI) can be used to define the depiction of the size and location of the fibroids within the uterus. The doctor can do imaging tests to confirm that have fibroids. These are tests that create a "picture" of the inside body without surgery. These tests might include:

- **Ultrasound** — uses sound waves to produce the picture. The ultrasound probe can be placed on the abdomen or it can be placed inside the vagina to make the picture.
- **Magnetic Resonance Imaging (MRI)** – uses magnets and radio waves to produce the picture

- **X-rays** – uses a form of radiation to see into the body and produce the picture

- **Computerized Tomography (CT)** – takes many X-ray pictures of the body from different angles for a more complete image. Some of the other techniques used for the diagnosis of uterine fibroids are,

  - Hysterosalpingogram
  - Laparoscopy
  - Hysteroscopy

  - **Hysterosalpingogram (HSG) or sonohysterogram**—An HSG involves injecting x-ray dye into the uterus and taking x-ray pictures. A sonohysterogram involves injecting water into the uterus and making ultrasound pictures. The doctor can look inside the uterus for fibroids and other problems, such as polyps. A camera also can be used with the scope.

  - **Laparoscopy** – The doctor inserts a long, thin scope into a tiny incision made in or near the navel. The scope has a bright light and a camera. This allows the doctor to view the uterus and other organs on a monitor during the procedure. Pictures also can be made.

  - **Hysteroscopy** – The doctor passes a long, thin scope with a light through the vagina and cervix into the uterus. No incision is needed. The doctor can look inside the uterus for fibroids and other problems, such as polyps. A camera also can be used with the scope.
Treatment

Most women with fibroids do not have any symptoms. For women who do have symptoms, there are treatments that can help. Talk with doctor about the best way to treat fibroids. She or he will consider many things before helping to choose a treatment. Some of these things include:

- The size of the fibroids
- The location of the fibroids
- Age and how close to menopause

Some of the treatments are

Medications

If fibroids have mild symptoms, doctor may suggest taking medication. Over-the-counter drugs such as ibuprofen or acetaminophen can be used for mild pain. If heavy bleeding during period, taking an iron supplement can keep from getting anemia.

Several drugs commonly used for birth control can be prescribed to help control symptoms of fibroids. Low-dose birth control pills do not make fibroids grow and can help control heavy bleeding. The same is true of progesterone-like injections (e.g., Depo-Provera). Other drugs used to treat fibroids are “gonadotropin releasing hormone agonists” (GnRHa). The one most commonly used is Lupron®. These drugs, given by injection, nasal spray, or implanted, can shrink fibroids. Sometimes they are used before surgery to make fibroids easier to remove. Side effects of GnRHAs can include hot flashes, depression, not being able to sleep, decreased sex drive, and joint pain. Most women tolerate GnRHAs quite well. Most women do not get a period when taking GnRHAs. This can be a big relief to women who have
heavy bleeding. It also allows women with anemia to recover to a normal blood count. GnRHs can cause bone thinning, so their use is generally limited to six months or less. These drugs also are very expensive, and some insurance companies will cover only some or none of the cost. GnRHs offer temporary relief from the symptoms of fibroids, once stop taking the drugs, the fibroids often grow back quickly.

**Surgery**

If fibroids with moderate or severe symptoms, surgery may be the best way to treat them. Here are the options:

- **Myomectomy** surgery is used to remove fibroids without taking out the healthy tissue of the uterus. It is best for women who wish to have children after treatment for their fibroids or who wish to keep their uterus for other reasons. The woman can become pregnant after myomectomy. But if fibroids were imbedded deeply in the uterus, it might need a cesarean section to deliver. Myomectomy can be performed in many ways. It can be major surgery (involving cutting into the abdomen) or performed with laparoscopy or hysteroscopy. The type of surgery that can be done depends on the type, size, and location of the fibroids. After myomectomy new fibroids can grow and cause trouble later. All of the possible risks of surgery are true for myomectomy. The risks depend on how extensive the surgery is.

- **Hysterectomy** surgery is used to remove the uterus. This surgery is the only sure way to cure uterine fibroids. Fibroids are the most common reason that hysterectomy is performed. This surgery is used when a woman's fibroids are large, if she
has heavy bleeding, is either near or past menopause, or does not want children. If the fibroids are large, a woman may need a hysterectomy that involves cutting into the abdomen to remove the uterus. If the fibroids are smaller, the doctor may be able to reach the uterus through the vagina, instead of making a cut in the abdomen. In some cases hysterectomy can be performed through the laparoscope. Removal of the ovaries and the cervix at the time of hysterectomy is usually optional. Women whose ovaries are not removed do not go into menopause at the time of hysterectomy. Hysterectomy is a major surgery. Although hysterectomy is usually quite safe, it does carry a significant risk of complications. Recovery from hysterectomy usually takes several weeks.

- **Endometrial Ablation** The lining of the uterus is removed or destroyed to control very heavy bleeding. This can be done with laser, wire loops, boiling water, electric current, microwaves, freezing, and other methods. This procedure usually is considered minor surgery. It can be done on an outpatient basis or even in a doctor’s office. Complications can occur, but are uncommon with most of the methods. Most people recover quickly. About half of women who have this procedure have no more menstrual bleeding. About three in 10 women have much lighter bleeding. But, a woman cannot have children after this surgery.

- **Myolysis** A needle is inserted into the fibroids, usually guided by laparoscopy, and electric current or freezing is used to destroy the fibroids.

- **Uterine Fibroid Embolization (UFE) or Uterine Artery Embolization (UAE)** A thin tube is thread into the blood ves-
sels that supply blood to the fibroid. Then, tiny plastic or gel particles are injected into the blood vessels. This blocks the blood supply to the fibroid, causing it to shrink. UFE can be an outpatient or inpatient procedure. Complications, including early menopause, are uncommon but can occur. Studies suggest fibroids are not likely to grow back after UFE, but more long-term research is needed. Not all fibroids can be treated with UFE. The best candidates for UFE are women who:

- have fibroids that are causing heavy bleeding
- have fibroids that are causing pain or pressing on the bladder or rectum
- don’t want to have a hysterectomy
- don’t want to have children in the future

1.3.3 Need for Ultrasound Imaging

Ultrasound imaging or ultrasonography is an important diagnosis method in medical analysis. The most noticeable advantages of ultrasound scanning are,

- Safety
- Cost effectiveness
- Speed
- Easy handling
- Portability
Ultrasound

Ultrasound is a popular medical imaging modality because it is non-invasive, versatile, with no known side effects, and the equipment used for ultrasonic scanning is small and inexpensive relative to other options. It is used for imaging soft tissues in organs such as liver, kidney, spleen, uterus, heart and brain. Ultrasound imaging is a common modality used for detecting fibroids. Ultrasound is based on the principle of sound wave echoes. Sound wave travels from the probe to the object, passes through it and is continuously reflected back to the probe from multiple points inside the object.

Ultrasound involves sound wave of frequency in the range of megahertz typically this ranges between 3.5-10 MHz. The reflected sound wave is converted back to electrical signals in the probe and transmitted to the processing device which displays the image on the monitor. Bright or white areas in the image represent high reflectivity in the body. Table 1.1 shows the various transducer frequencies used in ultrasound imaging and their penetration levels.

Table 1.1 Ultrasound Transducer frequency Ranges

<table>
<thead>
<tr>
<th>Low resolution</th>
<th>2.0MHz</th>
<th>High penetration</th>
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<tbody>
<tr>
<td>3.5 MHz</td>
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<td>5.0 MHz</td>
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<td>7.5 MHz</td>
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<td>10.0 MHz</td>
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<tr>
<td>High resolution</td>
<td>12.0 MHz</td>
<td>Low penetration</td>
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An ultrasound machine consists of two parts: the transducer and the analyzer. The transducer produces the sound waves that penetrate the body and also receives the reflected echoes. Transducers are built around piezoelectric ceramic chips. (Piezoelectric refers to electricity that is produced when pressure is put on certain crystals such as quartz). These ceramic chips react to sound waves by producing electric pulses (receiving). Bursts of high frequency electric pulses supplied to the transducer cause it to produce the scanning sound waves. The transducer then receives the returning echoes, translates them back into electric pulses and sends them to the analyzer- a computer that organizes the data into an image on a television screen.

Because the sound waves travel through all the body’s tissues at nearly the same speed – about 3,400 miles per hour, it takes few microseconds for each echo to be received. It can be plotted on the screen as a function of distance of penetration into the body. The relative strength of each echo, a function of the specific tissue or organ boundary that produced it, can be plotted as a point of varying brightness. In this way, the echoes are translated into a picture. Tissues surrounded by bone or filled with gas cannot be imaged using ultrasound, because the waves are blocked or become scattered.

Ultrasound imaging is a medical imaging technique that uses high frequency sound waves and their echoes. The technique is similar to the echolocation used by bats, whales and dolphins, as well as SONAR used by submarines. In ultrasound, the following events happen:

1. The ultrasound machine transmits high-frequency (1 to 5 megahertz) sound pulses into the human body using a probe.

2. The sound waves travel into the body and hit a boundary between tissues (e.g. between fluid and soft tissue, soft tissue and bone). Echoes are produced at any tissue interface where a
change in acoustical impedance occurs. On these images, the film density is proportional to the intensity of the echo (a more energetic echo would produce a darker or lighter dot on the film).

The intensity of the returning echo, that is the energy returned to the transducer, is determined by,

- The magnitude of the change in the acoustical impedance at the echoing interface
- The characteristics of the intervening tissue, and
- The normality (perpendicularity) of the interface to the transducer.
- The appearance of the echo on the film is also determined by the degree of amplification (gain) applied after the echo has been received by the transducer.

3. Hence some of the sound waves get reflected back to the probe, while some travel on further until they reach another boundary and get reflected.

4. The reflected waves are picked up by the probe and relayed to the machine.

5. The machine calculates the distance from the probe to the tissue or organ (boundaries) using the speed of sound in tissue (1,540 m/s) and the time of the each echo's return (usually on the order of millionths of a second).

6. The machine displays the distances and intensities of the echoes on the screen, forming a two dimensional image.
Transducer probe

The transducer probe is the main part of the ultrasound machine. The transducer probe makes and sends the sound waves and receives the echoes. The transducer probe generates and receives sound waves using a principle called the piezoelectric (pressure electricity) effect. The probe also has a sound absorbing substance to eliminate back reflections from the probe itself, and an acoustic lens to focus the emitted sound waves. Transducer probes come in many shapes and sizes. The shape of the probe determines its field of view, and the frequency of emitted sound waves determines how deep the sound waves penetrate and the resolution of the image. The piezoelectric effect also works in reverse.

If the crystal is squeezed or stretched, an electric field is produced across it. So if ultrasound hits the crystal from outside, it will cause the crystal to vibrate in and out, and this will produce an alternating electric field. The resulting electrical signal can be amplified and processed in a number of ways. So a second crystal can be used to detect any returning ultrasound which has been reflected from an obstacle.

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Applications of Ultrasound Imaging

Ultrasound has been used in a variety of clinical settings, like obstetrics, gynecology, and cardiology and in cancer detection. The main advantage of ultrasound is that certain structures can be observed without using radiation. Ultrasound can also be done much faster than X-rays or other radiographic techniques. Here is a short list of some applications of ultrasound:

1. Obstetrics and Gynecology
   - Measuring the size of the fetus to determine the due date
   - Determining the position of the fetus to see if it is in the normal head down position or breech
   - Checking the position of the placenta to see if it is improperly developing over the opening to the uterus (cervix)
   - Checking the fetus's growth rate by making many measurements over time
   - Detecting ectopic pregnancy, the life-threatening situation in which the baby is implanted in the mother's Fallopian tubes instead of in the uterus.
Determining whether there is an appropriate amount of amniotic fluid cushioning the baby.

Monitoring the baby during specialized procedures - ultrasound has been helpful in seeing and avoiding the baby during amniocentesis (sampling of the amniotic fluid with a needle for genetic testing).

Seeing tumors of the ovary and breast

2. Cardiology

Seeing the inside of the heart to identify abnormal structures or functions

Measuring blood flow through the heart and major blood vessels

In addition to these areas, there is a growing use for ultrasound as a rapid imaging tool for diagnosis in emergency rooms.

Three different modes of ultrasound are used in medical imaging:

- **A-mode.** Amplitude Modulation. This is the simplest type of ultrasound in which a single transducer scans a line through the body with the amplitudes of the returning echoes plotted onscreen as a function of time. This method is used to measures distances within the body and the size of internal organs. Therapeutic ultrasound aimed at a specific tumor or calculus is also A-mode, to allow for pinpoint accurate focus of the destructive wave energy.

- **B-mode.** Brightness Modulation. In B-mode ultrasound, a liner array of transducers simultaneously scan a plane through the body that can be viewed as a two dimensional image on
screen. Ultrasound probes containing more than 100 transducers in sequence form the basis for these most commonly used scanners, which cost about $50,000.

- **Doppler mode.** Doppler ultrasonography includes the capability of accurately measuring velocities of moving material, such as blood in arteries and veins. The principal is same as that used in radar guns that measure the speed of a car on the highway. Doppler capability is most often combined with B-mode scanning to produce images of blood vessels from which blood flow can be directly measured. This technique is used extensively to investigate valve defects, arteriosclerosis and hypertension, particularly in the heart, but also in the abdominal aorta and portal vein of the liver.

### 1.3.4 Problem of Ultrasound Image

The main disadvantage of ultrasound images is the poor quality of images, which are also affected by Speckle Noise. Therefore, in general, many of the image segmentation methods may not be suitable in case of ultrasound images. So for that some preprocessing methods are followed. Wavelet is the best method and then Phase-Base Level Set Segmentation (PBLS) is applied. It is well performed in the ultrasound images.

The quality of a medical ultrasonic image is often degraded due to the existence of speckle noise. Speckle is caused by interference effects of echoes from irresolvable random scatterers due to the coherent nature of ultrasound scanners. This occurs especially in imaging organs such as uterus, liver and kidney whose underlying structures are too small to be resolved by the transducer. Speckle, shown as granular pattern, degrades the image quality of B-scan, makes the low contrast objects, small high-contrast targets and
small differences in image brightness hard to be detected. Therefore, it is important to improve images quality by reducing speckle noise and also preserving the tissue structure.

Speckle reduction techniques include compounding methods by combining images of differing frequency content, of different spatial views, or through temporal filtering in the time domain. On the other hand, speckle reduction methods based on local statistics of the B-scan image involve adaptive filtering of the image to smooth out speckle while preserving structure. The nonlinear technique is used for performing contrast enhancement and noise reduction.

1.4 SPECKLE NOISE

Speckle is a characteristic phenomenon in laser, synthetic aperture radar images, or ultrasound images. Its effect is a granular aspect in the image. Speckle is caused by interference between coherent waves that, backscattered by natural surfaces, arrive out of phase at the sensor. Speckle can be described as random multiplicative noise. It hampers the perception and extraction of fine details in the image.

Speckle reduction techniques can be applied to ultrasound images in order to reduce the noise level and improve the visual quality for better diagnoses. Several methods have been proposed for speckle reduction. Here to enhance the ultrasound image using statistical approach based on wavelet transform. Wavelet speckle reduction in ultrasound was recently tackled.

Speckle is not a noise in an image but noise-like variation in contrast. It arises from random variations in the strength of the backscattered waves from objects and is seen mostly in RADAR and US imaging.
1.4.1 Definition of Speckle Noise

Speckle noise is defined as multiplicative noise, having a granular pattern. It is the inherent property of ultrasound image and SAR image.

1.4.2 Major Causes of Speckle Noise

Due to incorrect assumption that the ultrasound pulse always travels in a straight line, to and fro from the reflecting interference. Another source of reverberations is that a small portion of the returning sound pulse may be reflected back into the tissues by the transducer surface itself, and generates a new echo at twice the depth. Speckle is the result of the diffuse scattering, which occurs when an ultrasound pulse randomly interferes with the small particles or objects on a scale comparable to the sound wavelength.

1.4.3 Mathematical Model of Speckle Noise

Mathematically the image noise can be represented with the help of these equations below:

\[ V(x, y) = g[u(x, y)] + \eta(x, y) \]  \hspace{1cm} (1.1)

\[ g[u(x, y)] = \int \int h(x, y, x, y) u(x, y) \, dx \, dy \] \hspace{1cm} (1.2)

\[ D(x, y) = f[g(u(x, y))] \eta_1(x, y) + \eta_2(x, y) \] \hspace{1cm} (1.3)

Here \( u(x, y) \) represents the objects (means the original image) and \( v(x, y) \) is the observed image. Here \( h(x, y, x', y') \) represents the impulse response of the image acquiring process. The term \( \eta(x, y) \) represents the additive noise which has an image dependent random components \( f[g(w)] \eta_1 \) and an image independent random component \( \eta_2 \). A different type of noise in
the coherent imaging of objects is called speckle noise. Speckle noise can be modeled as,

$$V(x, y) = u(x, y)s(x, y) + \eta(x, y)$$  \hspace{1cm} (1.4)

where the speckle noise intensity is given by $s(x, y)$ and $\eta(x, y)$ is a white Gaussian noise.

The main objective of image-de-noising techniques is to remove such noises while retaining as much as possible the important signal features. One of its main shortcomings is the poor quality of images, which are affected by speckle noise. The existence of speckle is unattractive since it disgraces image quality and affects the tasks of individual interpretation and diagnosis. An appropriate method for speckle reduction is one which enhances the signal-to-noise ratio while conserving the edges and lines in the image.

Weiner filter was adopted for filtering in the spectral domain, but the classical Wiener filter is not adequate as it is designed primarily for additive noise suppression. Recently there have been many challenges to reduce the speckle noise using wavelet transform as a multi-resolution image-processing tool. Speckle noise is a high-frequency component of the image and appears in wavelet coefficients. One widespread method exploited for speckle reduction is wavelet shrinkage.

**Model of Speckle Noise**

The most critical part of developing a method for recovering a signal from its noisy environment seems to be choosing a reasonable statistical (or analytic) description of the physical phenomena underlying the data-formation process. The availability of an accurate and reliable model of speckle noise formation is a prerequisite for development of a valuable de-
speckling algorithm. In ultrasound imaging, however, the unified definition of such a model still remains arguable. Yet, there exist a number of possible formulae whose probability was verified via their practical use. A possible generalized model of the speckle imaging is,

\[ g(n, m) = f(n, m)u(n, m) + \xi(n, m) \]  \hspace{1cm} (1.5)

where \( g, f, u \) and \( \xi \) stand for the observed image, original image, multiplicative component and additive component of the speckle noise basically. Here \((n, m)\) denotes the axial and lateral indices of the image samples or, alternatively, the angular and range indices for B-scan images. When applied to ultrasound images, only the multiplicative component of the noise is to be considered, and thus, the model can be considerably simplified by disregarding the additive term, so that the simplified version of (1.4) becomes,

\[ g(n, m) = f(n, m)u(n, m) \]  \hspace{1cm} (1.6)

Homomorphic de-speckling methods take advantage of the logarithmic transformation, which, when applied its converts the multiplicative noise to an additive one. Denoting the logarithms of \( g, f \) and \( u \) by \( gl, fl, \) and \( ul \), respectively, the measurement model becomes,

\[ gl(n, m) = fl(n, m)ul(n, m) \]  \hspace{1cm} (1.7)

At this stage, the problem of de-speckling is reduced to the problem of rejecting an additive noise, and a variety of noise-suppression techniques could be evoked in order to perform this task
1.4.4 Need for Filtering

Speckle degrades the quality of US and SAR images and thereby reducing the ability of a human observer to discriminate the fine details of diagnostic examination. This artifact introduces fine-false structures whose apparent resolution is beyond the capabilities of imaging system. Another problem in Ultrasound data is that the received data from the structures lying parallel to the radial direction can be very weak, where as structures lying normal to the radial direction give stronger echo.

Filtering techniques can be classified as

- Incoherent processing techniques
- Image post processing

1. Incoherent Processing Techniques

These are based on the averaging of multiple images of the same scan plane, where the images are obtained by varying transducer frequency and view angle to achieve independent or partially uncorrelated speckle patterns. These imaging techniques increase target-detection capability of phased array scanning at the expense of increased system complexity and loss of spatial resolution.

2. Image Post processing

Speckle Suppression schemes based on image post processing involve adaptive, anisotropic diffusion and wavelet based filtering techniques. These techniques do not require any hardware modification in the image reconstruction system, and hence have found a growing interest. In this the
images are obtained as usual and the processing techniques are applied on the image obtained.

1.5 ORGANIZATION OF THE THESIS

The thesis has been organized as follows

**Chapter 1**: Introduction about the work undertaken.

**Chapter 2**: The review of Literatures.

**Chapter 3**: It describes the methodology. It explains Preprocessing, Segmentation of ultrasound uterine fibroid image and Mathematical models for the feature extraction and feature subset Selection Details of algorithm developed based on the feature subsets to implement enhanced decision support system for the classification of Fibroid tumor with results and discussion.

**Chapter 4**: Results and Discussion of the work

**Chapter 5**: Conclusion and future scope of the work followed by reference