CHAPTER 1

INTRODUCTION

1.1 OVERVIEW OF FEMALE REPRODUCTIVE SYSTEM

The female reproductive system includes the ovaries, fallopian tubes, uterus, cervix and vagina. These reproductive organs are located in the pelvis, between the urinary bladder and the rectum. The system is designed to produce female egg cells necessary for reproduction, called the ova or oocytes and transport the ova to the site of fertilization. In addition, the system produces female hormones that maintain the reproductive cycle.

The ovaries and uterus are the two important internal organs of the female reproductive system. The uterus is a pear-shaped organ and is located inside the pelvis immediately dorsal to the urinary bladder and ventral to the rectum. Ovaries are positioned in the pelvis as a pair on both sides of the uterus, inferior to the abdomen. It plays a significant role in reproduction and are responsible for generating the woman gamete and the female sex hormones (Eid & Shakweer 2014). The hypothalamus passes a gesture to the pituitary gland to discharge the luteinizing hormone and the follicle stimulating hormone. These hormones stimulate the follicle to oust the egg at the period of ovulation. If the egg is not fertilized, the egg, blood and tissues from the internal lining of the uterus are released during the menstrual time.
Figure 1.1 Female Reproductive System

Figure 1.1 shows the location of the ovary in the female reproductive system. Each month, during ovulation, within the ovary, the egg grows inside a small sac known as follicle. The matured egg is released from the follicle and it travels through the fallopian tube to the womb for fertilization. Once, the egg is released from the follicle, it becomes corpus luteum which produces female sex hormones that aids to prepare the egg for the next cycle (Eid & Shakweer 2014).

The blood is supplied to the ovary through the ovarian blood vessel. The blood vessel and vein enter and exit the ovaries at the hilus. Progesterone and estrogen hormones are necessary to prepare the uterus for menstruation, and the hypothalamus triggers the release of these hormones. Vagina is a duct that has an ability to grow up wider to deliver an infant and it joins the cervix to the outside of the body. Cervix is the lower part of the uterus and it is supple, during delivery the cervix can expand.
1.2 OVARY AND ITS COMPONENTS

Ovaries are the imperative organs of the female reproductive system and are the smooth ductless glands concerning the size and shape of an almond. This section discusses about the structure of a normal ovary and its components.

1.2.1 Normal Ovary

Normal ovary contains many follicles, in which one follicle grows faster in size that is about 2.0 mm per day. This follicle will mature to release the egg. Usually, the week before the midpoint of menstrual period, the follicle mature and the size of the matured follicle is of about 28.0 mm. Subsequent to the release of luteinizing hormone the ovulation will occur (Hiremath & Tegnoor 2010a). After releasing the egg, the dominant follicle forms a corpus luteum inside the ovary. The corpus luteum will disappear in few days.

(Source: http://www.clearpassage.com/what-we-treat/infertility/polycystic-ovarian/)

Figure 1.2 Normal ovary
Figure 1.2 shows the normal ovarian image. The number of follicles in a normal ovary ranges from 1-10. There are two types of follicles present in the normal ovary, antral follicles and dominant follicles. The antral follicles are small in size and in the range of 2.0-9.0 mm (Jokubkiene et al. 2012). The dominant follicles are also known as graafian follicles which grow faster in either of the ovary. These follicles are growing up to 28.0 mm in size and get ready for ovulation. The woman having normal menstrual period, ovulate in a regular interval.

1.2.2 Components of the Ovary

The surface, cortex and medulla are the important components of the ovary. The components of the ovaries are shown in Figure 1.3.

![Components of the ovary](http://teachmeanatomy.info/pelvis/female-reproductive-tract/ovaries/)

**Figure 1.3 Components of the ovary**

- **Surface**

  Simple cuboidal epithelium lines the surface of small excretory ducts in various organs and glands in the body. By lining the surface of various ducts, cuboidal cells are able to provide a layer of protection from...
abrasion, foreign particles, invading bacteria and excessive water loss to the underlying tissue. On the ovarian surface, simple cuboidal cells make up the ovarian surface epithelium. Their ability to rapidly divide and proliferate, enables them to repair ovulatory defects that occur on the ovarian surface, especially during the time of ovulation (Battaglia et al. 1997; Freeman 2014; Kaviprasanna et al. 2014; Mason et al. 2014).

- **Cortex**

  The cortex is the outer part of the ovary creased by a layer of cuboidal cells and contains bundles of connective tissue cells. It supports thousands of follicles. The stages of the follicle inside the ovary are primordial, primary, secondary and matured follicle. Each primordial follicle contains an oocyte surrounded by a single layer of follicular cells.

- **Medulla**

  Medulla is the inner part of the ovary composed of supporting stroma, connective tissues and a rich neurovascular network with blood vessels, nerves and lymphatic vessels which enters the hilum of ovary from the mesovarium (Rofe et al. 2013).

1.3 **OVARIAN ABNORMALITIES**

Nowadays, many women around the world are increasingly suffering from ovarian dysfunctions. Ovarian Cyst and PCOS are the most common aberrations found in the ovaries and these are identified based on the size and number of follicles present (Eid & Shakweer 2014).
1.3.1 Cyst Ovary

Every woman who is ovulating will form a small amount of fluid around the developing egg each month. The combination of egg, the special fluid-producing cells, and the fluid is called a follicle and is normally about the size of a pea. For unknown reasons, the cells that surround the egg occasionally form too much fluid, and this straw colour fluid expands the ovary from within. If the collection of fluid gets to be larger than a normal follicle, a Follicular Cyst is said to be present (Eid & Shakweer 2014). Follicular Cyst is a fluid filled sac presence in female ovary and is shown in Figure 1.4.

![Cyst Ovary Diagram](http://www.drugs.com/mcd/ovarian-cysts)

(Source : Mayo Foundation for Medical Education and Research. http://www.drugs.com/mcd/ovarian-cysts)

Figure 1.4 Cyst ovary

Normally, a Cyst ovary contains 1 or 2 follicles with size greater than 28.0 mm. Patients with follicular cyst develop symptoms like

- distressing sexual relations
- tenderness in the mammary glands
- stomach swell up, excruciating bowel motions and vomiting
- abdominal pain during menstruation cycle and unsettled abdomen
Women’s ovaries have different kinds of Cyst in them (Hiremath & Tegnoor 2010a). Cysts are a common cause of concern among women because of the fear of ovarian cancer. But, it is important that the vast majority of ovarian cysts are not cancer. Even though most of these Cysts are benign (not cancer), a small number of them could be cancer. Cysts that appear to be benign based on how they look on imaging tests, has to be repeatedly observed for proper diagnosis and treatment. Thus, periodic examination of the ovary is essential for a common and generative physical condition of the female.

1.3.2 PCOS Ovary

PCOS is the most common abnormality found in a female of reproductive age and about 12% – 21% of the women are affected by this disease (Khattab et al. 2006; Nandi et al. 2014; Wolf et al. 2014). A PCOS ovary is shown in Figure 1.5.

(Source : Mayo Foundation for Medical Education and Research http://www.mayoclinic.org/diseasesconditions/pcos/multimedia/polycystic-ovary-syndrome/img-20007768)

Figure 1.5 PCOS ovary
The Polycystic ovarian syndrome, or PCOS, is a condition in which a woman’s levels of the sex hormones estrogen and progesterone are out of balance. This leads to the growth of benign masses on the ovaries. PCOS is caused due to accumulation of incompletely developed follicles and the ovulation process does not occur when the ovaries are containing not fully matured follicles with eggs inside them. PCOS is characterized by the abnormalities in the reproductive system by excessive production of testoid, miscarriage and imbalance of stimulating hormones and luteinizing hormones. These hormones assist eggs to mature properly inside the ovaries. The imbalance of follicle stimulating hormone, results in rising of luteinizing hormone level, anovulation, failure to mature eggs, and insulin resistance (Hiremath & Tegnoor 2010a).

PCOS can cause the following problems in women

- Irregular periods or no periods, menstrual problems, heavy bleeding
- Infertility
- More hair on the face, abdomen, around the nipple, in toes and scalp hair thinning,
- Abrupt weight gain and weight loss, obesity
- Skin tags and acne
- Despair, mood swings, heart diseases, blood sugar, and diabetes.

Hence, early detection of PCOS is essential for its treatments (Almog et al. 2011). To differentiate polycystic ovary from normal ovary, standard criteria has been put forth by the American Society for Reproductive Medicine (ASRM) and the European Society of Human Reproduction and Embryology (ESHRE) (Yamanaka et al. 2004; Eltabbakh et al. 2008). These societies describe that the number of follicles in the polycystic ovaries are 12 or more with the size up to 10.0 mm.
1.4 DIAGNOSIS OF CYST AND PCOS

Physical examination, Pathology and Medical imaging are the different approaches for diagnosis of Cyst and PCOS abnormalities in ovarian images (Khattab et al. 2006; Nandi et al. 2014; Wolf et al. 2014).

- **Physical examination**
  
The women having the irregular menstrual period are initially checked by the physical examination like acne, hair, neck, tummy, mammary gland, thyroid and weight.

- **Pathology**
  
  For accurate diagnosis of Cyst and PCOS and to determine the origin and temperament of the diseases, laboratory examination of samples of blood tissues and other fluids are examined.

- **Medical imaging**
  
The ultrasound medical imaging has been identified as one of the consistent technique for the detection of aberrations in ovarian images.

1.5 ULTRASOUND IMAGING TECHNIQUE

Among the many medical imaging techniques, ultrasound imaging is being preferred to scan the internal organs and soft tissues other than bone or part of the body which contains air (Carovac et al. 2011). In women, pelvic ultrasound is frequently utilized to take a look into the growth of foetus all through the pregnancy, ovarian cancers, Cysts and PCOS in the ovary.
The ultrasound machine transmits high frequency sound waves into the patient body using a transducer probe to create ultrasound images of the organ. The piezoelectric effect is used in the transducer probe to send and receive the sound pulses. The sound waves travel into the human body and hit the boundary between tissues (Carovac et al. 2011). The reflected echoes are transformed into electrical signals in the probe. The machine displays the distances and intensities of the echoes on the screen, that forms a two dimensional image. The shape and size of the organs and tissues are measured from that image for further diagnosis.

Transducer probes are available in many shapes and sizes. The shape of the probe determines its field of view. Abdominal probes are moved along the surface of the body and angled to obtain the various views (Carovac et al. 2011). Vaginal probes are used to visualize the organs within the pelvic cavity even more clearly. A radiologist for scanning the ovary, rotates the probe progressively for recognizing the follicle and measuring its dimension more accurately (Raine-Fenning et al. 2007). The ultrasound imaging technique is non-invasive in nature, adaptable, safety, cost effective and speeder than X-rays. This technique does not use ionizing radiation like CT scan and X-ray. However, the major disadvantage of using ultrasound imaging in medicine is the operator error.

1.6 NEED FOR THE RESEARCH

Reading ultrasound image and repeated measurements of the size and shape of follicles are the primary means of detecting abnormalities in ovarian images. This manual tracing is time consuming and susceptible to inter-operator variation. Also, tracing of follicles are more prone to subjective error due to homogeneity between follicles and complex background, and for this reason well-trained and experienced radiologists are required.
Many crucial features are necessary for differentiating normal and abnormal ovaries and accurate extraction of the feature set is essential for successful diagnosis. Hence, there is need for a supportive Computer Assisted System (CAS) for detection of ovarian abnormalities that

a) solve the human made error  

b) assist radiologists in preparing good reports  

c) help experts in making accurate diagnosis

1.7 OBJECTIVE OF THE RESEARCH

The objective of this research is to develop a Computer Assisted System (CAS) for automatic detection of follicles in ovarian images and classify them as Normal, Cyst and PCOS ovaries. The various phases in the Computer Assisted System (CAS) are

- Preprocessing for removal of speckle noise in ovarian images
- To develop new techniques for segmentation of follicles from ultrasound ovarian images.
- Extract the follicle features, analyze and classify the ovarian types.

The Computer Assisted System (CAS), thereby provide more accurate detection of aberrations in ovaries and painless diagnosis procedure for patient comfort in the midst of their ailment.

1.8 PROBLEM DEFINITION

This research proposes to develop a Computer Assisted System (CAS) for automatic detection of aberrations in ultrasound ovarian images for medical diagnosis.
The various stages in the development of Computer Assisted System proposed in this research are

a. Preprocessing

Preprocessing helps to improve the segmentation process of ovarian images. Various filtering techniques are applied to denoise the ultrasound ovarian images and their performances are analyzed using different metrics. A proper choice of filtering technique will facilitate the manipulation and visualization of the ovarian images for a computer.

b. Follicle detection

Follicles are the means of detecting aberrations in ovarian images, the Cyst and PCOS. New techniques are proposed in this research for segmentation of follicles to improve the accuracy in diagnosis.

- The Otsu method is applied on ovarian images for follicle segmentation and this method is modified to improve the segmentation results. Conventional region based active contour method is found to be better for segmentation, but needs manual interaction to choose the initial contour. Hence, to automate the segmentation process region based active contour method is hybridized with the modified Otsu method.

- Threshold based methods play a vital role in image segmentation. However, optimal selection of threshold value is important in medical image segmentation, as accuracy is a major concern. Hence, threshold selection is treated as an optimization problem.
The following nature inspired algorithms are proposed to find the optimal threshold value for follicle segmentation.

- Particle Swarm Optimization (PSO) and its variants
- Pigeon Inspired Optimization (PIO)
- Invasive Weed Optimization (IWO) and its variant.

The experiments are conducted on different types of ovarian images. The performances of the proposed methods are evaluated.

c. Feature extraction and Classification

From the segmented follicles, features relevant for identification of true follicles and aberrations are extracted. Support Vector Machine (SVM) is used to classify the ovarian images as Normal, Cyst and PCOS.

1.9 OVERVIEW OF COMPUTER ASSISTED SYSTEM (CAS)

The development of a Computer Assisted System (CAS) for detection of aberrations, namely, the Cyst and PCOS in ultrasound ovarian images is focused for providing valuable information to the radiologists. Figure 1.6 gives an overview of the various phases of the proposed Computer Assisted System (CAS). The Computer Assisted System (CAS) uses ultrasound ovarian images as an input.

Input ultrasound ovarian images are preprocessed with Lee, Kuan, Frost, Gaussian, Wiener, Median, Hybrid median, Modified hybrid median and Fuzzy filters. The performances of the filters are analyzed using performance metrics. The results reported that the Modified hybrid median and Fuzzy filters are denoised better and hence hybridized.
Therefore, the ultrasound ovarian images are filtered with hybrid fuzzy filter for removal of speckle noise.

![Diagram](image)

**Figure 1.6 Block diagram of the Computer Assisted System**

Four major techniques are proposed for automatic detection of follicles in the segmentation phase. Initially, Otsu method and modified Otsu method are used for segmenting the follicles. Modified Otsu method has given better segmentation results and therefore this segmented result is used as an
initial mask in hybrid region based active contour method. The choice of this initial mask has facilitated hybrid region based active contour method to identify the follicles in less number of iterations. However, as threshold based technique can be viewed as an optimization problem, nature inspired optimization algorithms, PSO and its variants, PIO and IWO and its variant are proposed to find the optimal threshold for segmentation of follicles. The variant of IWO, namely, the Modified Invasive Weed Optimization (MIWO) technique has reported good performance.

From the segmented follicles, geometrical features are extracted to identify true follicles and classify the ovarian images as Normal, Cyst and PCOS. SVM classifier has been used for classifying ovarian images, due to its superior performance in classifying images.

Hence, the proposed Computer Assisted System (CAS) can be implemented with hybrid fuzzy filter for preprocessing, MIWO method for segmentation and SVM classifier to classify the ovarian types. This Computer Assisted System (CAS) will be a promising solution for radiologists and gynecologists.

1.10 STRUCTURE OF THE THESIS

This dissertation is organized in to eight chapters.

Chapter 1 initiates the thesis by a brief introduction about the female reproductive system, ovaries, ovarian abnormalities, diagnostic procedures and ultrasound imaging technique. It states the need for research, objective and the problem definition. The chapter also presents an overview of the proposed Computer Assisted System (CAS) for detecting aberrations in ovarian images.
Chapter 2 presents a survey on speckle noise reduction, ovarian image segmentation techniques, other segmentation techniques, evolutionary algorithms in segmentation, feature extraction and classification. The survey concludes with the necessity for improvement in segmentation for development of Computer Assisted System (CAS).

Chapter 3 describes the various filtering techniques for speckle noise reduction. The performances of the filters are evaluated and the results are plotted.

Chapter 4 discusses the conventional Otsu, modified Otsu and hybrid region based active contour methods for detection of follicles from the ultrasound ovarian images. The performances of the methods are compared and the experimental results are analyzed.

Chapter 5 elaborates the nature inspired optimization algorithms, namely, Particle Swarm Optimization (PSO) and its variants, Pigeon Inspired Optimization (PIO) and Invasive Weed Optimization (IWO) and its variant to find the optimal threshold value for segmentation of follicles in ultrasound ovarian images. These algorithms maximize the fitness function, the between-class variance. Experiments are done on the ultrasound ovarian images and the performances of the algorithms are evaluated.

Chapter 6 discusses about feature extraction and classification of the ovarian images using Support Vector Machine (SVM) classifier.
Chapter 7 compares the segmented results of the MIWO algorithm used in the Computer Assisted System (CAS) with the opinions of medical experts.

Chapter 8 concludes the dissertation with a summary of the research.