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Early Detection of Endometriosis: Integrating Medical Imaging and Machine Learning Algorithms for Non-Invasive Diagnosis

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Abstract
Endometriosis appears when tissue which should exist inside the body matches the uterus lining through it spreads outside the uterus. The out-of-place tissue inside the body performs as a lining similar to the uterus by getting thicker and bleeding during the menstrual cycle. Under normal circumstances this blood would exit through the uterus but external tissue prevents it from escaping which produces various complications. Women typically experience endometriosis through its development throughout ovaries along with fallopian tubes and pelvic lining. The spread of this condition is an extremely rare occurrence that moves beyond the pelvic area. Post-menstrual bleeding outside the uterus results in endometrioses or ovarian cysts as well as tissue irritation while screening tissue develops along with adhesive fibrous bands that fuse organs together. Women dealing with Endometriosis face reduced pregnancy prospects at below 2%. Endometriosis impacts ten percentage of all worldwide female population. Infertility occurs in 24% to 50% of women having endometriosis. Medical Imaging alongside Pelvic Exams and Blood Tests and Laparoscopy help in the diagnosis of this condition. Medical professionals struggle to detect endometriosis since diagnostic symptoms and standard procedures show distinct patterns between patients. Health records from patients and medical documentation and symptom-level measurements together with image-based feedback enable our models to operate support vector machines and random forests and deep learning neural networks. Model accuracy testing was performed in addition to specific and sensitive tests that compared against standard diagnostic procedures like laparoscopy. Evaluation results prove machine learning models improve medical diagnosis efficiency through their ability to accelerate endometriosis disease treatment while minimizing procedural invasiveness. New diagnostic systems for gynecological healthcare practice require development following performance-enhancement assessments of critical features.

Keywords: *Endometriosis, Machine learning, Random Forest, Support Vector Machine.*

1. Introduction
The common gynecological condition endometriosis occurs in 5–10% of reproductive-aged women (Goldstein & Cohen, 2023, p. 1) as endometrial tissue grows outside the uterus according to Goldstein & Cohen, 2023, p. 1. The condition brings forth severe health problems that include ongoing pelvic pain and fertility complications and decreased life satisfaction (Zhang et al., 2023, p. 2). The existing diagnostic evaluation requires extensive time and effort comprising pelvic exam along with ultrasound and MRI and possibly requiring surgical laparoscopy (Goldstein & Cohen, 2023, p. 1). The diagnostic process currently takes between 6–10 years from the first symptoms appearing leading to inadequate treatment as well as increased patient discomfort and diminished quality of life (Goldstein & Cohen, 2023, p. 1). Accurate non-invasive screening tools that provide easy access represent key requirements in the

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prevention of endometriosis. Endometriosis prediction research involves three non-invasive methods such as biomarkers (Bendifallah et al., 2022, pp. 9–10), genomic analysis (Goldstein & Cohen, 2023, p. 1), and symptom-based questionnaires (Goldstein & Cohen, 2023, p. 1). The current detection methods lack adequate sensitivity and specificity to accomplish the gold standard performance of laparoscopic surgery according to Bendifallah et al. (2022, p.1). Most research investigates patient groups who have already sought advanced diagnostic examinations even though their findings do not translate well to early-stage symptom diagnosis in women (Goldstein & Cohen, 2023, p. 1). Machine learning through its method gives promising possibilities to overcome these limitations. The application of ML algorithms reveals hidden complex patterns between patient symptoms and characteristics thus building better diagnostic systems (Goldstein & Cohen, 2023, p. 2). The application of ML for predicting endometriosis demonstrates strong accuracy rates through combining various patient data points like clinical information and medical images (Bendifallah et al., 2022, p. 5). Early detection and reduced diagnostic delays require models that can analyze self-reported symptoms but available statistical data remains insufficient (Goldstein & Cohen, 2023, p. 2). This study aims to detect Endometriosis at early stage by using image processing and Convolutional Neural Network algorithm. By using image processing techniques like Guassian filter, sobel filter and Clahe method it will enhace the quality of the image and when it combine with CNN it will helps to detect Endometri at early stage thus increase the accuracy level of prediction.[6]

1.1. Endometriosis

Endometriosis represents a chronic gynecological condition which causes regular pain during its occurrence among women who have reached their reproductive years. The condition consists of endometrial-like tissue starting inside the uterus yet growing in other locations outside this organ. The ectopic endometrial tissue develops in both pelvic locations as well as extending to ovaries and fallopian tubes and pelvic ligaments as well as potential distant areas. Several theories attempt to explain endometriosis despite the unknown trigger that leads to this disorder.[1-4]

1.1.1. Retrograde Menstruation

Menstrual blood with endometrial cells flowing backward through fallopian tubes into pelvic cavity where it implants and grows.

1.1.2. Lymphatic or Hematogenous Spread

Endometrial cells spread through the lymphatic system or bloodstream to other parts of the body

1.1.3. Metaplasia of the Coelomic Cells

Pelvic cavity cells change to resemble endometrial cells.[5]

1.1.4. Immune Factors

The immune system cannot correctly recognize and get rid of the ectopic endometrial cells. No matter what the reason, the ectopic endometrial tissue reacts to hormonal regulation, thickening and bleeding during the menstrual cycle. With this bleeding this body cannot get out of (escape the body), inflammation will occur, the scar tissue (adhesions) will appear and the developing on the ovary of the cyst (endometriomas).

1.2. Symptoms

Symptoms are variable in extent from mild to severe. Common symptoms include:

Most significant symptom: This pain may include painful menstrual periods (dysmenorrhea), constant pelvic pain, pain during intercourse (dyspareunia).

Anemia: Excessive bleeding from excessive menstrual bleeding (menorrhagia).

Infertility: Endometriosis can also interfere with fertility by damaging fallopian tubes, ovaries, and uterus.

Gastrointestinal problems: Such as bloating, constipation, diarrhea, abdominal pain limitations of this condition.

Urinary problems: Such as painful urination (dysuria) and frequent urination.

Chronic fatigue: it is a common symptom.

Diagnosis: Diagnosis is difficult due to variability of symptoms and there is not one single definitive test. Diagnosis typically involves:

Tenderness and abnormalities: A physical exam, the pelvic exam.

Transvaginal Ultrasound: An ultrasound

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performed through the vagina to see pelvic organs and detect cysts (transvaginal ultrasound).

MRI: May be used in further evaluation of pelvic structures using MRI.

Laparoscopy: Minimally invasive surgical procedure through small incision to look inside the pelvic organs and later for tissue sample enough to confirm. It is considered the gold standard for diagnosing the condition.

Treatment: Treatment depends on the degree to which symptoms occur and the likelihood of wanting children later. Options include:

Pain management: Over-the-counter pain relievers, prescription pain medications, and hormone therapy.

Hormone therapy: Suppresses the menstrual periods and reduces endometrial (the tissue that lines the uterus) growth.

Surgery: Removal of endometrial implants, cysts and adhesions. Laparoscopy is the term used for either minimally or maximally invasive surgery, depending on how far the surgeon has advanced.

It is worth noting that endometriosis is a complex disease and there is great variability in symptoms and progression in different people. Treatment at an earlier stage and focusing on aspects to impact quality of life and possibly fertility risks.

2. Methodology

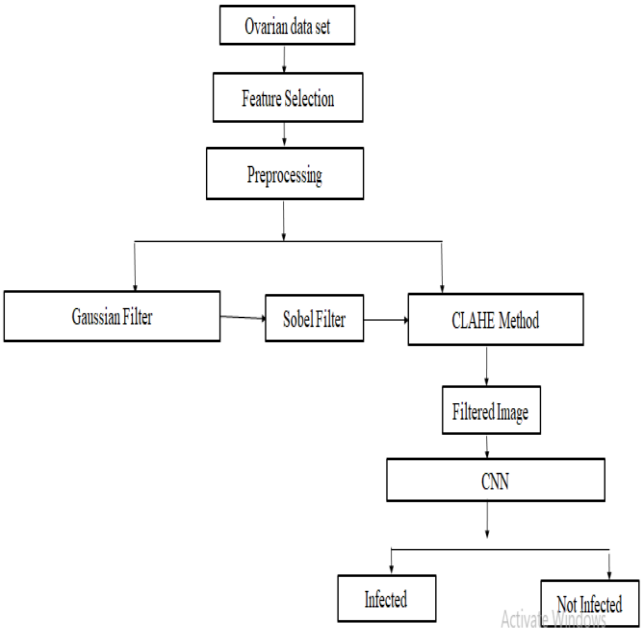

Figure 1 Methodology of Work

2.1. Data Collection

Data for the Endometriosis study was collected from Kaggle websites. Around 450 patients dataset are collected from the websites. (Figure 2)

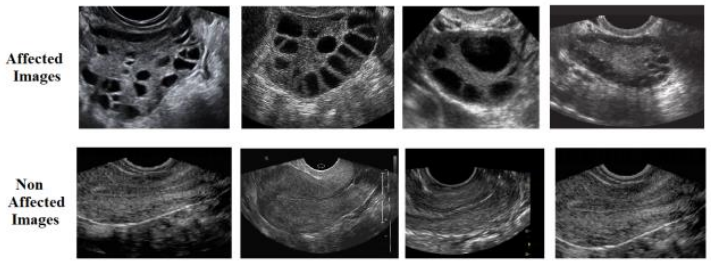

Figure 2 Ultrasound Image Dataset of Endometriosis.

2.2. Feature Selection

Upon gathering the data set, it will proceed to the feature selection phase, for which we will utilize the Boruta Algorithm. It computes the Information gain for every attribute then compares each attribute's value and removes the least significant one[7]

2.3. Preprocessing

For preprocessing, we utilize the CLAHE method, Gaussian filter, and Sobel filter. The Gaussian filter is effective at removing noise from photographs. The Sobel filter is used to determine the edges of the cyst. Furthermore, the contrast of the image is enhanced using the CLAHE technique, which splits the picture into smaller regions and equalizes the histogram of each region.

2.4. Convolutional Neural Network

CNNs are unique because of their convolutional layers. They can automatically and adaptively build spatial hierarchies of information from images. CNNs have three parts. The most important part is the convolutional layer which alters the input image in ways. The resulting set of feature vectors is sent to the next layer of the network. It is the duty of the convolutional layers of CNNs to extract and learn features from the image using specialized filters that capture local hierarchies and patterns. Furthermore, pooling layers define features more appropriately, reduce the computational burden by decreasing the spatial resolution of feature maps, and lessen the chances of overfitting the model. Compoundly, these

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layers make it possible, As depicted in Figure 3, for CNNs convolutional neural networks to perform complex tasks such as detecting objects or classifying images as well as analyzing medical images. **(**Figure 3)

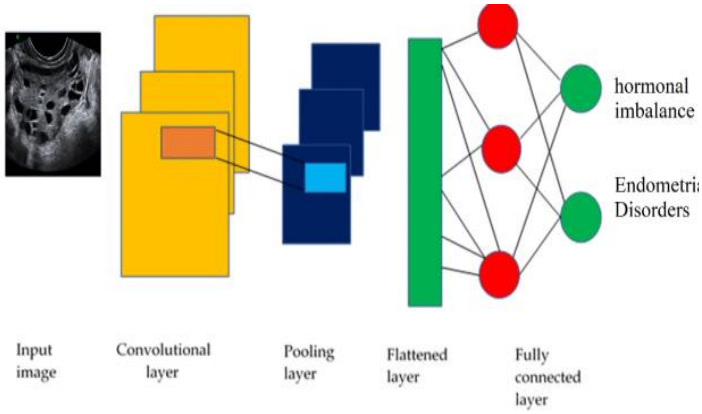

Figure 3 Working of Convolutional Neural Network

Results and Discussions

Table 1 Sensitivity and Specificity

S.NO	CLASSIFICATION MODEL	SENSITIVITY %	SPECIFICITY %
1	KNN	90.13	91.13
2	SVM	93.13	93.21
3	PSO	94.29	94.41
4	GB	95.16	95.08
5	SE-RN	96.83	96.39
6	CNN	98.23	98.73

Table 1 shows the sensitivity and specificity of different algorithms, By comparing all these algorithm Convolutional Neural Network gives highest accuracy.

Table 2 Precision, Recall and F-Measures

S.NO	CLASSIFICATION MODEL	PRECISION	RECALL	F MEASURE
1	CAT BOOST	80.63	76.54	85.86
2	YOLO	82.64	79.32	88.68
3	SVM	84.05	82.54	92.06
4	GDB	83.54	84.52	94.16
5	SE-RESNET	90.63	89.64	95.83
6	CNN	95.44	96.45	96.23

Table 2 Shows the Precision, Recall and F-Measures of various classification algorithm. Among that Convolutional Neural Network algorithm shows highest accuracy when compared to other.[8]

Conclusion

Endometriosis is diagnosed using image analysis and CNNs because the ability of CNNs to process and learn from medical images is superior to means other than classification algorithms. In comparison to Support Vector Machine, Random Forests, and other algorithms CNN give best accuracy. They also outperform other algorithms in precision, sensitivity, and specificity in the diagnosis of endometriosis. These results decrease the need for invasive procedures such as laparoscopy, since the accurate diagnosis is attributed to their deep feature hierarchical spatial learning. The prompt and accurate clinical recognition of endometriosis helps in improving the care provided to the patients by easing the decision-taking processes.

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