RESEARCH ARTICLE OPEN ACCESS

AI based automated diagnosis of polyps in colonoscopy: An introduction for researchers and Physicians in healthcare

Yogesh Chaudhari*, R. Senthil Kumar**, Darshee Baxi***
**(Research Scholar, Computer Science and Engineering Department, Navrachana University, Vadodara,*
*** (School of Engineering and Technology, Navrachana University, Vadodara*
**** (School of Science, Navrachana University, Vadodara*
Corresponding Author : Yogesh Chaudhari

ABSTRACT
Artificial Intelligence (AI) aims to make the system work with better accuracy and speed which will minimize false detections and medical errors. Recent developments and advancements in computational, data capture and data transfer techniques have encouraged the researchers to leverage the AI tools to design and develop new methods and approaches in various fields of healthcare. This paper aims at exploring the status of research work done and discusses the future possibilities of AI in colonoscopy. The purpose of this is paper is to present the information in a way that helps colonoscopists and researchers to understand the perspective of other's discipline concerning to colonoscopy. Researchers specialized in one discipline need to understand either of disciplines as the present study is the intersection between the two disciplines of a healthcare and an AI. This interdisciplinary knowledge and its applications will play significant role to improve accuracy of diagnosis and quality of treatment given to the patient. Automated systems for polyp detection are developed and designed - a system that harnesses the AI and computer vision. Misdiagnosing and medical errors result into undetected polyps which are considered as a major cause of colorectal cancer (CRC). CRC is the second leading cause of cancer related deaths and is primarily diagnosed by examination with colonoscopy.
Keywords - colonoscopy, Artificial Intelligence, polyp, imaging, diagnosis, colorectal cancer

Date of Submission: 07--12-2019 Date Of Acceptance: 18-12-2019

I. INTRODUCTION

Recently a large portion of diagnostic colonoscopy are using AI consistently, studying clients for interface improvements and to validate the predictions of AI systems to that of reported by the doctor. AI will ease the documentation and paperwork of endoscopists, raise adenoma discovery rate (ADR), diminish medical expenses for pathology and improve patient survival. [1]

The colonoscopy has proved been most significant diagnostic technique for screening of intestine as it can both distinguish and remove benign and cancerous polyps that lead to Colorectal cancer (CRC). CRC is the second leading cause of cancer related death in the United States and many of the cases benign lesions (adenomas) gradually transforms into malignant lesions.

II. INTRODUCTION TO AI

Artificial Intelligence (AI) aims to mimic various human cognitive functions. These cognitive functions specifically includes an active role of subject in the processes of receiving and interpreting inputs, processing of inputs, transforming received data into information, storing of received and processed information, classification, recognition, detection and retrieval of information that facilitates the subject to navigate the world around it with past experience at the same time gaining the experience through present inputs to improve the experience of navigation and the accuracy of cognitive functions in the future. AI is very broad term covering intelligent algorithms in which machine learning (ML) is a subset of AI and it is a superset of deep learning (DL). [10]

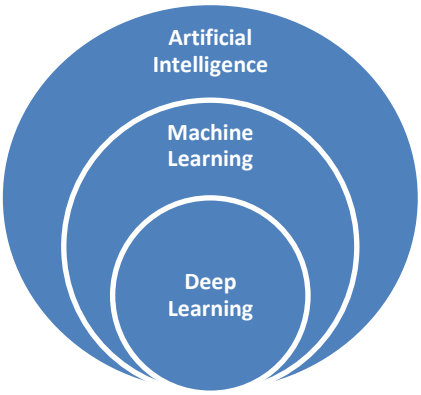

Fig. 1 AI is a superset of ML which is subsequently is a superset of DL

The human cognitive functions can be mimicked by a computer, a robot or a subject. Hence study in AI revolves around how human brains think, learn, decide, apply and act primarily when it tries to solve the problems. The final outcome of this study is intelligent software installed on compatible hardware with the aim to improve computer functions which are related to human knowledge concerning perception, reasoning, learning, problem-solving, knowledge representation, planning and ability to manipulate.

Table 1: common terminologies used in AI are

SN	Terminology	Meaning
1	Artificial intelligence	Machine intelligence that has cognitive functions similar to those of humans such as "learning" and "problem solving."
2	Machine learning	Mathematical algorithms which is automatically built from given data (known as input training data) and predicts or makes decisions in uncertain conditions without being explicitly programmed
3	Artificial neural networks	Multilayered interconnected network which consists of an input, hidden connection (between the input and output layer), and output layer
4	Deep learning	Subset of machine learning technique that composed of multiple-layered neural network algorithms
5	Overfitting	Modeling error which occurs when a certain learning model tailors itself too much on the training dataset and predictions are not well generalized to new datasets
6	Spectrum bias	Systematic error occurs when the dataset used for model development does not adequately represent or reflect the range of patients who will be applied in clinical practice (target population)

2.1 CHALLENGES IN AI

Number of areas has experienced and some areas are now experiencing the advantages of utilizing AI. Despite the fact that AI is gaining preference and demand with increasing prominence, there are number of challenges faced in AI usage as discussed below.

- A vanishing gradient

For improved accuracy, as more layers are included to Deep Neural Network with activation function, the gradients of the error function approaches to zero resulting into increasing the difficulty to train the network. Activation functions, similar to the Sigmoid function, maps an enormous input space into a little input space on scale of 0 and 1. In this scenario, large variation in the input values will result into a little change or no change in the Sigmod function. Subsequently, the derivative turns out to be small that can be interpreted as training process takes too long and the prediction accuracy of the model decreases. The solution to this problem is to use ReLU based activation functions that results into large derivatives unlike Sigmoid and Tanh as activation functions. Utilization of residual networks or batch normalization of inputs are other proposed approaches to address the vanishing gradient problem.

- Overfitting or Underfitting

Overfitting happens when a model is trained on the information and noise to the degree that it reversely affects the prediction accuracy of the model on new information. This implies that the noise and outlier in input data are learned as idea by the model. Overfitting means better prediction yet poor generalization to the information not quite the same as training information.

Underfitting means a model predicts in a way that is neither better for training information nor sum up to new information. Underfitting gives inferior performance on both the training information and to any other information.

Use of a resampling technique (k-fold cross validation), pruning or regularization can abstain from overfitting and to estimate the model accuracy. Underfitting can be controlled using more training information and by using reduced features given by feature selection.

- Insufficient computing capacity

The greater part of the operations performed in CNN are matrix operations. A CPU works on each element of a matrix discretly while a GPU which comprises of cores forms grid and processes matrix elements in parallel making GPU orders of magnitude faster than a CPU. GPUs being good at (Multiply and Accumulation) MAC is almost the perfect candidate to perform multiple concurrent operations. Generally a single GPU gives better performance than 5 CPUs with similar

specification. A specific type of circuit called a Field Programmable Gate Array (FPGA) and AI accelerator are promising further speedup in AI implementations.

- Bias and Variance

Models are assessed on the basis of prediction error on a new test data set. For a given input x, applying a function f predicts an output y'. The prediction error is the difference between the actual output y and predicted output y'.

$$\text{Prediction error } L(x,y) \quad = \sum_{k=1}^{n} y_k - f(x_k)$$

…….. (eq. 1)

$$\text{Error} = \text{Reducible error} + \text{Irreducible error}$$

…….. (eq. 2)

Irreducible error is error that cannot be controlled as it is the error caused by unknown variables.

Reducible error is defined in terms of both bias and variance that are forms of prediction error.

$$\text{Reducible Eroor} \quad = \text{Bias}^2 + \text{Variance}$$

…….. (eq. 3)

High bias means model does not capture the complexity of input information and hence causes algorithm to miss relevant relationship between input and output information. Bias and variance are inverse of each other in a sense that if we try to reduce the value of bias then the variance increases and if we try to reduce the value of variance then bias increases. [11]

Table 2: Relation of bias and variance

Bias/ Variance	Low	High
Low	Model is accurate and consistent on an average	Model is close to accurate but inconsistent on average
High	Model is inaccurate and consistent on an average	Model is inaccurate and inconsistent on an average

Regularization significantly reduces the variance without substantially increasing bias.

- Scarcity of training data and data sources

Data is at the center of any AI based framework and it is difficult to accurately estimate the minimum size of data sufficient for obtaining low bias and low variance to control the reducible error. To have more information is consistently the favored choice to deliver consistent performance but to increase the size of input data, replication of data is poorly conceived notion and data augmentation is a practical approach.

III. INTRODUCTION TO COLONOSCOPY

Colonoscopy is the visual assessment of the digestive organs - specially the large intestine, jejunum and the ileum parts of small intestine. The visual assessment can be intrusive with a camera introduced on an flexible tube that passed through anal canal or it can be non-invasive also called as virtual colonoscopy in which a CT scan of abdomen and pelvis is done to make 3-D images. The pictures and recordings caught in colonoscopy with the assistance of camera enables medical professional to take subjective decisions in detection of polyps and in diagnosis of ulceration and polyps. [9]

It likewise expedite for biopsy and to expel suspected colorectal cancer lesions. It is achievable to remove polyps of little size (near one millimeter or less) during colonoscopy is being performed. The removed polyps are additionally investigated in research laboratories with the microscope and additionally can further be tested with tumor markers to decide whether those polyps are precancerous, benign or have malignancy.

IV. POLYPS AND ITS TYPES

Polyps in the colon are the most widely recognized and it is possible to observe the development of polyps in places that include - ear canal, cervix, stomach, nose, uterus, bladder and throat. Most polyps are benign, which means they're noncancerous. These polyps are developed because of irregular or uncontrolled cells development and can eventually turn into malignant or cancerous.

A polyp is a little development of excess tissue that structures on the lining of the colon. Although undesirable, they aren't uncommon. Colon and rectal polyps observed in around 25 percent of men and women of the age 50 and more. In view of what shape a polyp takes when it develops, polyps can be ordered in two classes.

- **Sessile polyps** lie flat against the lining of colon, otherwise called the mucous membrane. They're more typical than recently suspected and harder to recognize in colon malignancy screening.

- **Pedunculated polyps** are mushroom-like tissue developments that join to the outside of mucous membrane of colon by long and thin stalk.

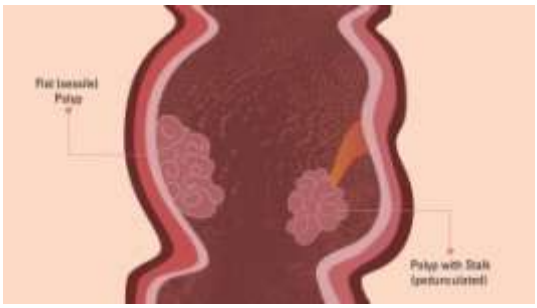

Fig. 2 Sessile polyp (left) and Pedunculated polyp (right) in the image

The polyps can also be classified on the basis of the cancerous risk carried by these polyps as discussed in table 3 and table 4. [8] This classification is as given below

Table 3: Polyp classification and cancer risk

Sr. No.	Type of polyp	How common	Cancer risk
1	Inflammatory	Typically found In people with inflammatory bowel disease, (Crohn's disease or ulcerative colitis)	Low; growths generally benign
2	Hamartomatous	Found in people with polyposis syndrome like Peutz Jaeghers, Cowden's, or Juvinille Polyposis	Generally noncancerous
3	Hyperplastic	Usually small and located at end of colon and the rectum	Considered lower risk
4	Adenomatous (tubular adenoma)	Most common type - about 70 percent of polyps found in colon	Most do not develop into cancer, although larger polyps pose higher threat
5	Villous or tubulovillous adenoma	Make up about 15 percent of polyps	Most do not develop into cancer, although larger polyps pose higher threat
6	Serrated Adenoma	Make up 10 to 15 percent of polyps	Cause 20 to 30 percent of colon cancers
7	Adenocarcenoma	Make up 2 percent of polyps	It is 100 percent malignant

Table 4: Polyp classification and treatment

Sr.No.	Type of polyp	Treatment	Remark
1	Inflammatory	Removal during colonoscopy	-
2	Hamartomatous	-	are generally genetic syndromes
3	Hyperplastic	Removal during colonoscopy	found on the right side of colon
4	Adenomatous (tubular adenoma)	Removal during colonoscopy; Regular follow-ups needed to screen for and remove new polyps	Size less than ½ inch
5	Villous or tubulovillous adenoma	Can be flat and tougher to remove; smaller villous adenoma are removed during colonoscopy; larger polyps may require surgery	Size less greater than ½ inch and can have mixture with tubular
6	Serrated Adenoma	Hard to detect during colonoscopy	these polyps appear with a "saw-tooth" border of their glands

7	Adenocarcenoma	Surgery, Radiation therapy, Chemotherapy, Targeted therapies.	-

The colon polyp and cancer risk is shown in Fig. 3 below

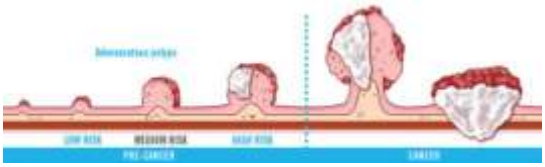

Fig. 3 Polyps and malignancy

4.2 FACTORS AFFECTING THE DETECTION OF POLYPS

The above classification is valuable in structuring of frameworks that can help in automated detection and recognition of polyps utilizing algorithms. The different parameters influence the detection of polyps and consideration of these parameters will help in structuring of framework with better accuracy and precision in detection of polyps. [4]

The detection of polyps commonly influenced because of large varieties in polyps based on factors like

- Location
- Shape (morphology)
- Texture
- Size
- Color and
- Existence of various polyp-like mimics

Other than the factors listed above the polyp detection during live video can be affected by factors like

- Camera motion
- Strong light reflections
- Lack of focus of wide angle lens
- Presence of vascular patterns
- Bubbles, fecal material and other distracter

The variations in polyp appearance and conditions while recording the video plays important role in detection of polyps. This detection is further dependent on the practitioner can be described as interobserver and intraobserver variance

- Interobserver variance stems from differences in expertise
- Intraobserver variance affected by experience, personal well-being, levels of distraction and stress.

V. QUALITY PARAMETERS OF COLONOSCOPY

Accomplishment of CRC screening is reliant on quality of colonoscopy. Quality is significant in colonoscopy and in the previous 15 years the awareness has built up with the fact that the goal achievement of colonoscopy to counter malignant growth and to limit post colonoscopy complexions is primarily dependent on the expertise and capability of the colonoscopist. Colonoscopists vary significantly in the count of precancerous polyps they identify during colonoscopy and in how frequently they perform colonoscopy in light of both ordinary and anomalous discoveries. [5] The nature of an assessment contrasts among colonoscopists and normal execution of colonoscopy by gastroenterologists is better than that of primary care physicians. There is notable variation among gastroenterologists of same expertise and specialty in their rate of detection of precancerous polyps. While the colonoscopy is brilliant standard to analyze malignant growth and gastrointestinal problems, sometimes it have demerits like bleeding, injuries, draining and puncturing or distress to the patients sue to presence of sharp angulations or circling of the colon. These wounds may prompt some new malignancies or can also have effects that are favorable to malignant tumor. To measure the quality of colonoscopy following six objective parameters are defined

1. Adenoma Detection Rate (ADR)It defined as the ratio of polyps detected out of the total polyps and should more than 20%.
2. Cecal intubation rate Cecal intubation is defined as passage of the colonoscope tip to a point. It's expected value is at least 90%
3. Withdrawal Time

The colonoscopy should be performed for minimum of 6 minutes if biopsy is not performed

4. Comfort score (Less than 10%)

Participant experiences moderate or severe discomfort and no more than 10% of patients should experience the discomfort

5. The Boston Bowel Preparation Scale (BBPS)

The diagnostic accuracy of colonoscopy requires thorough visualization of the colonic mucosa, making bowel preparation is a vital element of the procedure. BBPS is a valid and reliable instrument for rating the quality of bowel preparation during colonoscopy

6. Complication score

The patients experience complications like bloating, abdominal pain, mild bleeding, diarrhea, constipation, and nausea even after 30 days of colonoscopy and should be less than 1 in 1000 patients.

The advantages of colonoscopy exceed the potential risks with patients examined in experienced hands.

VI. QUALITY PARAMETERS OF AUTOMATED SYSTEMS

The utilization of AI in healthcare is at present an area of incredible developments, particularly as to the investigations in medical images. Selection of an AI in clinical practice requires precision for its clinical utility. [3] [6] The parameters discussed in section 5 are defined for manual colonoscopy. The present section defines the quality parameter to measure the performance of AI based system designed for polyp detection. These quality Parameters of AI systems designed for APDS

1. Sensitivity:

The sensitivity of the automated system is calculated using equation (4).

$$\text{Sensitivity} = \frac{\text{Number of correctly detected frames}}{\text{Number of polyp positive frames}} \quad \text{…….. (eq. 4)}$$

The ideal and expected value of sensitivity is 1.

2. Specificity:

The sensitivity of the automated system is calculated using equation (5).

$$\text{Specificity} = \frac{\text{Number of detected negative frames}}{\text{Total Number of polyp negative frames}} \quad \text{…….. (eq. 5)}$$

The ideal and expected value of specificity is 1.

3. Accuracy:

The accuracy of the automated system is calculated using equation (6).

$$\text{Accuracy} = \frac{\text{Number of accurate detected positive frames}}{\text{Total Number of polyp positive frames}} + \frac{\text{Number of accurate detected negative frames}}{\text{Total Number of polyp negative frames}} \quad \text{…….. (eq. 6)}$$

The ideal and expected value of accuracy is 1.

4. False Positive Ratio:

The False positive ratio of the automated system is calculated using equation (7).

$$\text{False Positive Ratio} = \frac{\text{Number of incorrectly positive detected frames}}{\text{Total Number of polyp negative frames}} \quad \text{…….. (eq. 7)}$$

The ideal and expected value of False Positive Ratio is 0.

5. False Negative Ratio:

The False negative ratio of the automated system is calculated using equation (8).

$$\text{False Negative Ratio} = \frac{\text{Number of positive frames not detected}}{\text{Total Number of polyp positive frames}} \quad \text{…….. (eq. 8)}$$

The ideal and expected value of False Negative Ratio is 0.

VII. CONCLUSION

In spite of the fact that the completely computerized recognition of polyps is unsolved issue, the automated detection of polyps can assist the colonoscopist to improve the ADR and performance in colonoscopy. Most of the different methods and calculations that are executed for programmed identification of polyps from colonoscopic pictures or recordings depend on convolutional neural network (CNN). [7]

The performance of colonoscopy must be improved for welfare of patients by detection of polyps in their earliest stage. detection of polyps in earliest stage aids in providing most accurate treatment and also in better management of treatment. The different automated approaches proposed in literature will additionally contribute in significant reduction of human and medical decreasing the frequencies of colonoscopy and hence thereby improving the scores of quality parameters of colonoscopy.

The challenges in design of and development of automated system are the design of completely automated framework and the plan and advancement of framework that meets the perfect and anticipated estimations of quality parameters.

REFERENCES

Journal Papers:

[1]. Kudo SE, Mori Y, Misawa M, Takeda K, Kudo T, Itoh H, Oda M, Mori K, Artificial intelligence and colonoscopy: Current status and future perspectives, Digestive Endoscopy, Jul;31(4), 2019, 363-37

[2]. Bray F, Ferlay J, Soerjomataram I, Siegel RL, Torre LA, Jemal A, Global cancer statistics 2018: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries, Cancer Journal for Clinicians, Nov;68(6), 2018, 394-424

[3]. Seong Ho Park , Kyunghwa Han, Methodological Guide for Evaluating Clinical Performance and Effect of Artificial Intelligence Technology for Medical Diagnosis and Prediction, Radiology journal of Radiological Society of North America, Jan Volume 286, 2018, 800-809

[4]. Ronald M. Summers, Christopher F. Beaulieu, Lynne M. Pusanik, James D. Malley, R. Brooke Jeffrey, Jr, Daniel I. Glazer, Sandy Napel, Automated Polyp Detector for CT Colonography: Feasibility Study, Radiology journal of Radiological

Society of North America, Jan Volume 216, 2012, 800-809

[5]. Thomas J W Lee, Matthew D Rutter, Roger G Blanks, Sue M Moss, Andrew F Goddard, Andrew Chilton, Claire Nickerson, Richard J Q McNally, Julietta Patnick, Colin J Rees, Colonoscopy quality measures: experience from the NHS Bowel Cancer Screening Programme, Gut – Biomedical Journal (BMJ), Volume 61, Issue 7 , 2012

[6]. Joseph R. England and Phillip M. Cheng, Artificial Intelligence for Medical Image Analysis: A Guide for Authors and Reviewers, American Journal of Roentgenology, March 2019, Volume 212, Number 3 , 513-519

[7]. Rikiya Yamashita, Mizuho Nishio, Richard Kinh Gian Do, Kaori Togashi, Convolutional neural networks: an overview and application in radiology, Springer - Insights into Imaging, August 2018, Volume 9, Issue 4, pp 611–629

[8]. Cathy Walsh, Colorectal polyps: cancer risk and classification, Gastrointestinal Nursing Vol. 15, No. 5

[9]. Messmann, Helmut, Atlas of Colonoscopy: Techniques - Diagnosis - Interventional Procedures, Thieme, 2006

[10]. June-Goo Lee, Sanghoon Jun, Young-Won Cho, Hyunna Lee, Guk Bae Kim, Joon Beom Seo, Namkug Kim, Deep Learning in Medical Imaging: General Overview, Korean Journal of Radiology, 2017 Jul-Aug;18(4):570-584

Proceedings Papers:

[11]. S. Lawrence ; C.L. Giles , Overfitting and neural networks: conjugate gradient and backpropagation, IEEE Proceedings of the IEEE-INNS-ENNS international joint conference on neural networks - IJCNN , 2000

Yogesh Chaudhari "AI based automated diagnosis of polyps in colonoscopy: An introduction for researchers and Physicians in healthcare" International Journal of Engineering Research and Applications (IJERA), vol. 9, no. 12, 2019, pp 06-12