3D STEREOGRAPHIC ENDOSCOPE WITH AUTOMATED IMAGE ANALYSIS FOR CERVICAL CANCER EARLY DETECTION

BY

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ABSTRACT

Cervical cancer is the second most found cancer in women. In 2018, Human Papillomavirus and Related Cancers report that every year there are 8,622 cases of cervical cancer and 5,015 deaths from cervical cancer. Therefore, diagnosis for cancer has become essential to be done every year. Cervical cancer screening consists of 3 methods that are cytological examination or Papanicolaou (Pap) smear, Human Papilloma Virus (HPV) virus test, and colposcopy. Colposcopy is performed after finding that the patient is the risk of having cervical cancer by having abnormal result from cytological examination or a positive result from HPV test. It is the final examination before being diagnosed with cervical cancer. Therefore, it requires relatively high precision and expertise in colposcopy operating. Besides, vaginal speculum must be used to expose the entire cervix and the surrounding vaginal walls, causing injury. Hence, this project will design a system to reduce the injuries by requiring less testing time, but still the same performance. It consists of two smaller endoscopes segment that has resolution 1600*1200 pixels which aligned in the hardware that made from medical grade material. It allows you to visualize more comprehensive images in a three-dimensional (3D) image system. Besides, this project has a system that will help process whether the resulting image is likely to be normal or cancerous. It can specify by using artificial intelligence (AI) with the performance of 75% accuracy. And it has a real-time image capture during endoscopy with the foot switch. Then, send the results of the examination to the doctor to help for making decisions.

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Ornnattida Ornketphon

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LIST OF SYMBOLS/ABBREVIATIONS

Symbols/Abbreviations	Terms
2D	Two dimensional
3D	Three dimensional
ABS	Acrylonitrile-Butadiene-Styrene
AGI	Artificial General Intelligence
AI	Artificial Intelligence
ANI	Artificial Narrow Intelligence
API	Application Programming Interface
ASCII	American Standard Code for Information Interchange
ASC-US	Atypical Squamous Cells of Undetermined Significance
ASI	Artificial Super intelligence
AUC	Area Under the Curve
CBC	Complete Blood Count
CBN	Cross-iteration batch normalization
CCD	Charge-Coupled Devices
CCTV	Closed-Circuit Television
CEO	Chief Executive Officer
CIN	Cervical Intraepithelial Neoplasia
CMOS	Complementary Metal-Oxide Semiconductor
CNN	Convolutional neural networks
CSP	Cross-Stage-Partial connections
DACs	Digital-to-Analog Converters system
DES	Diethylstilbestrol
DM	Diabetes mellitus
DNA	Deoxyribonucleic acid
FBS	Fasting Blood Sugar
FN	False Negative

LIST OF SYMBOLS/ABBREVIATIONS (CONTINUED)

Symbols/Abbreviations	Terms
FP	False Positive
FPN	Feature Pyramid Networks
FPS	Frame Per Rate
GPU	Graphic Processing Unit
GUI	Graphic User Interface
HD	High Definition
HIV	Human Immunodeficiency Virus
HPV	Human Papilloma Virus
HSIL	High-grade squamous intraepithelial lesion
ICG	Indocyanine green
LED	Light Emitting Diode
LSIL	Low-grade squamous intraepithelial lesion
LVM	Low-carbon Vacuum Melted
MIS	Minimally Invasive Surgery
NASA	National Aeronautics and Space Administration
NCD	Non-Communicable Diseases
NLP	Natural Language Processing
OCR	Optical Character Recognition
PAN	Pan aggregation network
Pap	Papanicolaou
RCNN	Region-based convolutional neural network
RNN	Recurrent neural networks
ROC	Receiver Operating Characteristic
SAT	Self-adversarial-training
SCJ	Squamocolumnar junction
SSD	Single Shot Multibox Detector
STD	Sexually Transmitted Disease

LIST OF SYMBOLS/ABBREVIATIONS (CONTINUED)

Symbols/Abbreviations	Terms
TN	True Negative
TP	True Positive
TTA	Test Time Augmentation
UPS	Uninterruptible Power Supplies
USB	Universal Serial Bus
VIA	Visual Inspection with Acetic acid
WHO	World Health Organization
WRC	Weighted-Residual-Connections
YOLO	You Only Look Once

CHAPTER 1
INTRODUCTION

1.1 Background

Cancer is the second cause of death globally, which 1 of 6 deaths are caused by cancer, as the statistics from the World Health Organization (WHO) report that cervical cancer is the second most found cancer in women. Besides, in 2018 Human Papillomavirus and Related Cancers report that every year there are 8,622 cases of cervical cancer and 5,015 deaths from cervical cancer. In 2025, the number of new cases is estimated to rise to about 13,082 cases annually and 7,871 deaths. A cancer diagnosis is essential to be done every year, especially in women who regularly examine cervical cancer screening.

A cervical cancer diagnosis has two main steps. First is the screening test, which consists of the Papanicolaou (Pap) test and Human Papilloma Virus (HPV) test. If the Pap test results are abnormal or the HPV test result is positive, it will lead to the second step, which is the colposcopy. Colposcopy is an examination of the epithelium inside the cervix, vagina, vulva, and rectum with a colposcope to find the pre-cancerous lesions and cancerous lesions and receive the treatment as quickly as possible. Colposcopy is the method that needs to insert the vaginal speculum into the vagina to keep it open during the diagnosis. A colposcope, which can magnify the cervix and vagina cells, will help observe abnormal cells. However, colposcopy requires high precision and expertise. Thus, the diagnosis takes a long time, and inserting a speculum into the vagina can cause injuries.

This research will design and build a system that can reduce injuries, use less time for diagnosis, and maintain efficiency. It consists of a 3D stereographic endoscope made from 2 small Complementary Metal-Oxide Semiconductor (CMOS) cameras, and it can give a more comprehensive image in the 3D system. Including the artificial intelligence system can help diagnose whether the resulting image is likely to be cancerous or not and the severity of that cancer. This system can process in real-time and collecting images for the doctor to make decisions or observe the development of cervical cancer cells.

1.2 Objectives

1.2.1 To develop innovation in cervical cancer diagnosis by creating a 3D colposcope.

1.2.2 To increase the efficiency and accuracy of cervical cancer diagnosis by using AI.

1.3 Scopes

This project focuses on designing cameras and systems to assist in the diagnosis of cervical cancer by colposcopy that consists of

1.3.1 Two cameras are CMOS cameras that allow access to the cervix without injuring and creating 3D images.

1.3.2 An artificial intelligence system can help process images of whether a patient has cervical cancer or not by comparing it with image data based on a database.

1.4 Benefits

1.4.1 The 3D image reveals the object's depth and gives a more comprehensive view than the two-dimensional (2D) image.

1.4.2 A small colposcope gives more convenience when using.

1.4.3 Artificial intelligence systems can specify the severity, increasing the efficiency and accuracy of a cervical cancer diagnosis.

1.4.4 Artificial intelligence systems can reduce the time processing of diagnosis.

1.4.5 The system can collect images for the doctor to make decisions or observe cervical cancer cells' development.

1.5 Work plan

Table 1.1 The work plan since August 2020 to May 2021

No	Activities	Months									
		Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.
Planning stage											
1.	Set the scope of research work.										
2.	Research the methods, principles, and equipment of cervical cancer diagnosis.										
3.	Plan the research process.										
Preparation stage											
4.	Design and develop the stereographic camera in the hardware part.										
5.	Design and develop the stereographic camera in the software part.										

Procedure stage											
6.	Build the stereographic camera and 3D systems.										
7.	Test, improve, and fix the camera performance.										
8.	Collect images, previews, or data from various sources.										
Evaluation stage											
9.	Design and develop a deep learning algorithm to diagnosis cervical cancer with a colposcope.										
10.	Test the images obtained from the sampling and train the diagnosis system to be able to distinguish images.										

11.	Test by running the image to be diagnosed on the program, viewing the results, and solving it.										
12.	Test and troubleshoot all device and system interoperability.										
13.	Do the project report										

1.6 Technical term

1.6.1 Stereographic camera is a low-magnification camera. It is used to illuminate opaque objects such as bees, fabrics, or tissues by the stereographic camera's light source, which will come from above and below. Therefore, the item to be transmitted can be either opaque or translucent [20].

1.6.2 Endoscope is a small, tubular medical instrument that uses light and water to visualize a patient's spine from the inside out. The lens of scope is shaped at an angle that allows the surgeon to see abnormalities around and under the back's physical structures. Other medical instruments are inserted through the endoscope, so only 7.9 mm incision is needed [15].

1.6.3 3D image is a combining the surfaces of each side of the work as a single figure, making it possible to see the shape and surface of the workpiece’s width, length, and thickness. It makes the 3D image look similar to looking at the actual work. 3D images that are created in drawings are of many types. Each type has differences in the angle of illustration, both the exact size and the work piece's size in a drawing. The author of the model must study each type of 3D image's characteristics to practice drawing properly [17].

1.6.4 Deep learning is computer software that mimics the neurons' functioning in the human brain, a subset of machine learning [43].

1.6.5 Colposcopy examines the woman's cervix, vagina, and external genitals to help make the diagnosis. This examination will enlarge the area's image more clearly, allowing the doctor to identify problematic tissue and possibly disease, especially cervical cancer. Doctors usually perform colposcopy only when cervical diagnosis results in abnormalities [32].

1.6.6 Cancer screening is the early detection of cancer when the patient is asymptomatic. The purpose of the screening is to reduce the morbidity and mortality rates among those tested, where the test is inexpensive and can be performed in large populations [21].

1.6.7 Cervical cancer is cancer that occurs in the cervix in women. It has abnormal vaginal discharge symptoms, purulent-like discharge, abnormal vaginal bleeding other than menstrual blood, bleeding after sex, or those in menopause bleeding after menopause [48].

1.6.8 AI is a machine with functions capable of understanding and mastering a range of knowledge, such as cognition, learning, reasoning, and problem-solving [3].

CHAPTER 2
LITERATURE REVIEW

2.1 Female reproductive system

The female reproductive system is a system that functions similarly to the male reproductive system. In addition to producing reproductive cells (oocytes) and female hormones, the female reproductive system is responsible for maintaining the fertilized egg cells to develop. As an embryo until it is born. The female reproductive system consists of

2.1.1 External genitalia

External genitalia is an organ that can see from outside. It may be called the vulva or pudendum, the mone pubis, the labia majora, the labia minora, the clitoris, the vestibule, and the Bartholin's gland, the paraurethral gland, and the perineum [29], as shown in figure 2.1.

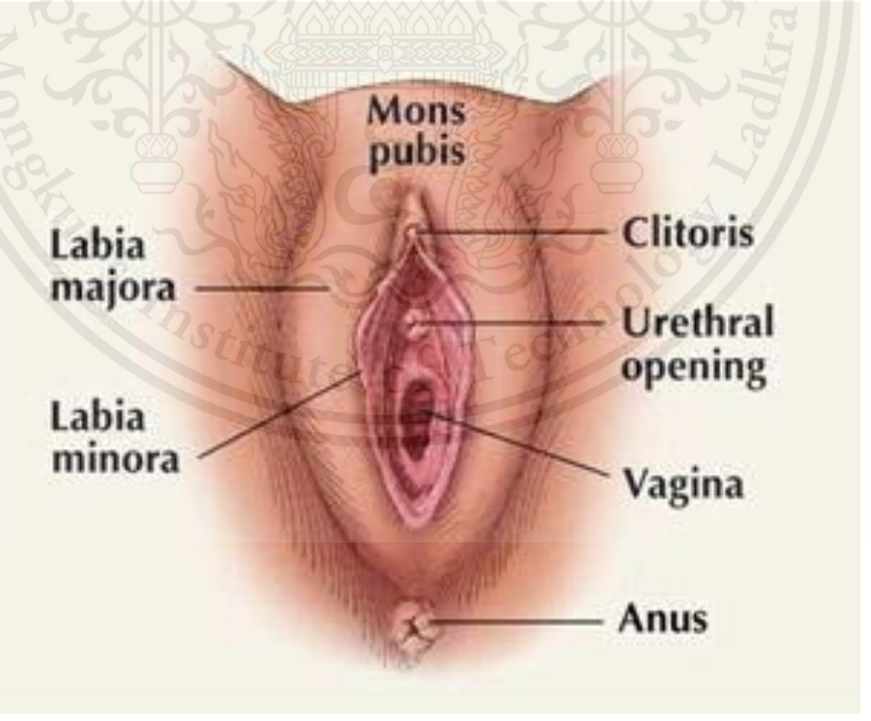

Figure 2.1 The female external genitals [2].

2.1.1.1 The mone pubis is a raised skin over the pubic symphysis. In females, the hairline is triangular, with the tops pointing downwards.

2.1.1.2 The labia majora is the skin that comes from the bottom of the mone pubis. A convex shape, separated into two lobes, converges on the back at the perineal area.

2.1.1.3 The labia minora is a raised skin layer that forms two small red petals inside the labia majora. The frontal lobes separate into two lobes, and the upper lobes reach each other to create a skin covering the clitoris is called “Prepuce of the clitoris.” The lower lobes connect under the clitoris, called “the frenulum of the clitoris.” The dorsal end of the clitoris wrap around the opening of the vagina and the urethra, then meet each other behind the back, called the “fourchette.” The labia minora has no hair growing out.

2.1.1.4 The clitoris is a small bump. There is an erectile tissue structure that’s a large number of blood vessels and sensory nerve endings. Therefore, a tear in this area, which can occur during labor, can be painful, loss of blood, and challenging to stitch.

2.1.1.5 The vestibule area is between the two labia minora, from the clitoris down to the labia majora. This area has various pipe openings as follows.

- The urethral orifice is located 1 cm above the clitoris.
- The vaginal orifice is next to it, with the hymen closed.
- One pair each of the greater vestibular gland orifice and the orifice of the para-urethral gland.

2.1.1.6 The more significant vestibular gland is a small gland the size of a green pea. Forms a lubricating and alkaline mucus to reduce vaginal acidity.

2.1.1.7 The hymen is a tissue that covers the opening of the vagina, and in the center, there is a small opening, with the hymen being flexible. In some children, the hymen does not have space, so the vagina is entirely closed, so menstrual blood cannot flow out. It is called an “imperforate hymen.”

2.1.1.8 The perineum is a diamond-shaped area connected from the pubic bone to the two ischial tuberosity and the coccyx. Still, suppose a straight line connects the two ischial nodes. In that case, the perineal area divides into two triangles: the anterior triangle and the urogenital triangle, where the entire external genitalia is located, and

behind it is called “the anal triangle.” It is the opening gap in the anus. It can find between the anus and the vagina. A lump of rigid and robust connective tissue inside called the “Perineal body,” which is essential is the adhesion point of many skeletal muscles that support the organs within the pelvic floor from moving out. The perineal often torn while giving birth. Without suturing, the internal pelvic organs, especially the uterus, may move out through the vagina. Therefore, to prevent the perineal tear during delivery, the perineal area must be cut, called “episiotomy,” to open the vagina to facilitate delivery. When the baby is born, then sew it back together [29].

2.1.2. Internal reproductive organs

It consists of several organs, as shown in Figure 2.2.

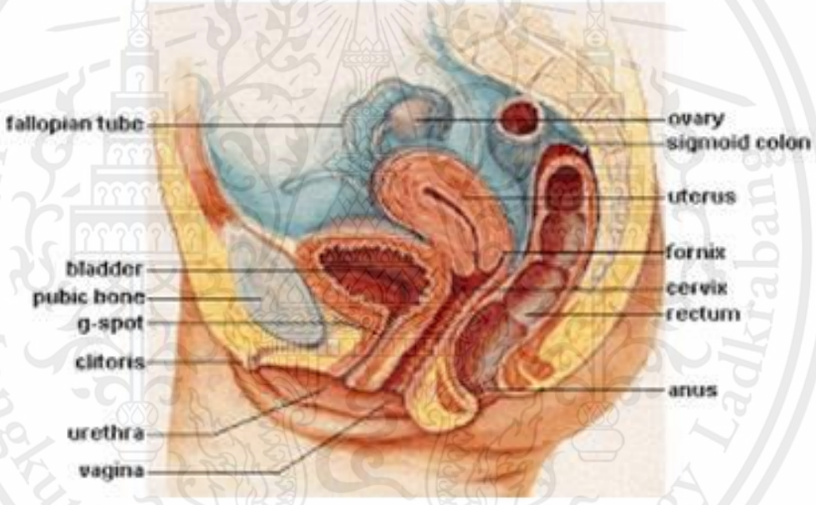

Figure 2.2 The internal genital organs of the female [2].

2.1.2.1 Vaginal canal is a visceral cavity located between the urethra and the anus, approximately 7-8 cm long, which is the channel for the passage of the sperm to fertilize the egg in the uterus or fallopian tubes as well as the baby’s exit while giving birth. The internal walls of the vagina are membranes that are almost adjacent and can be separated. It can significantly stretch, and the vulva has a small gland that acts to drive mucus to the vagina, called Bartholin Grand, in normal conditions. The vagina is acidic from the conversion of glycogen to Lactic Acid, a type of bacteria. It is a condition that helps prevent microbial infection, and the vulva is covered by a thin

membrane called the hymen. Hymen tear, but in some people, it may have been since birth.

2.1.2.2 Ovary is a small white organ. It is shaped like a cashew nut the size of a Marian Plum seed, with 2 of them located on both left-right uterine wings. It is connected to the uterus by the uterus or fallopian tubes.

2.1.2.3 Oviduct or Fallopian Tube is a connection between the ovaries and the uterus. It serves as the passage of the egg from the ovary into the uterus. The fallopian tube is the area where the sperm becomes fertilized with the egg.

2.1.2.4 Uterus is an organ of the female reproductive system located in the pelvis. It looks like a guava pear that is usually about 3 inches long. It can expand significantly according to the child's growth and shrink back to normal after birth.

2.2 Uterus

The uterus is the largest female internal reproductive organ. It is located in the pelvis and between the bladder, which is in front of it, and the rectum. A part connects to the cervical vagina, called the cervix, as shown in Figure 2.3. The inside of the uterus is a narrow cavity with a thick and robust muscle endometrium. It has many blood vessels and can change throughout the menstrual cycle due to sex hormones, estrogen, and progesterone. The uterine wall is peeled off during menstruation, but it expands to the fertilized egg implantation and gradually grows into a fetus when pregnant. After birth, the uterine wall returns to its original state within 45 days.

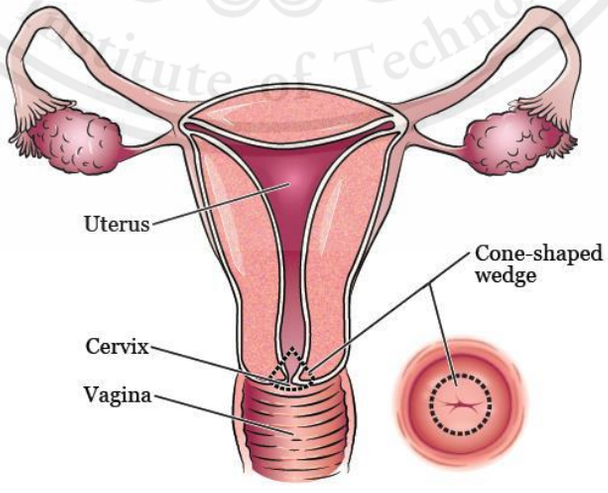

Figure 2.3 The stage of the uterus [54].

2.2.1 Uterine function

Menstruation is caused by the peeling of the uterus's lining after the egg is not on the side, which will have a tear in the blood vessels causing the blood to flow out, also known as menstruation [58], as shown in Figure 2.4.

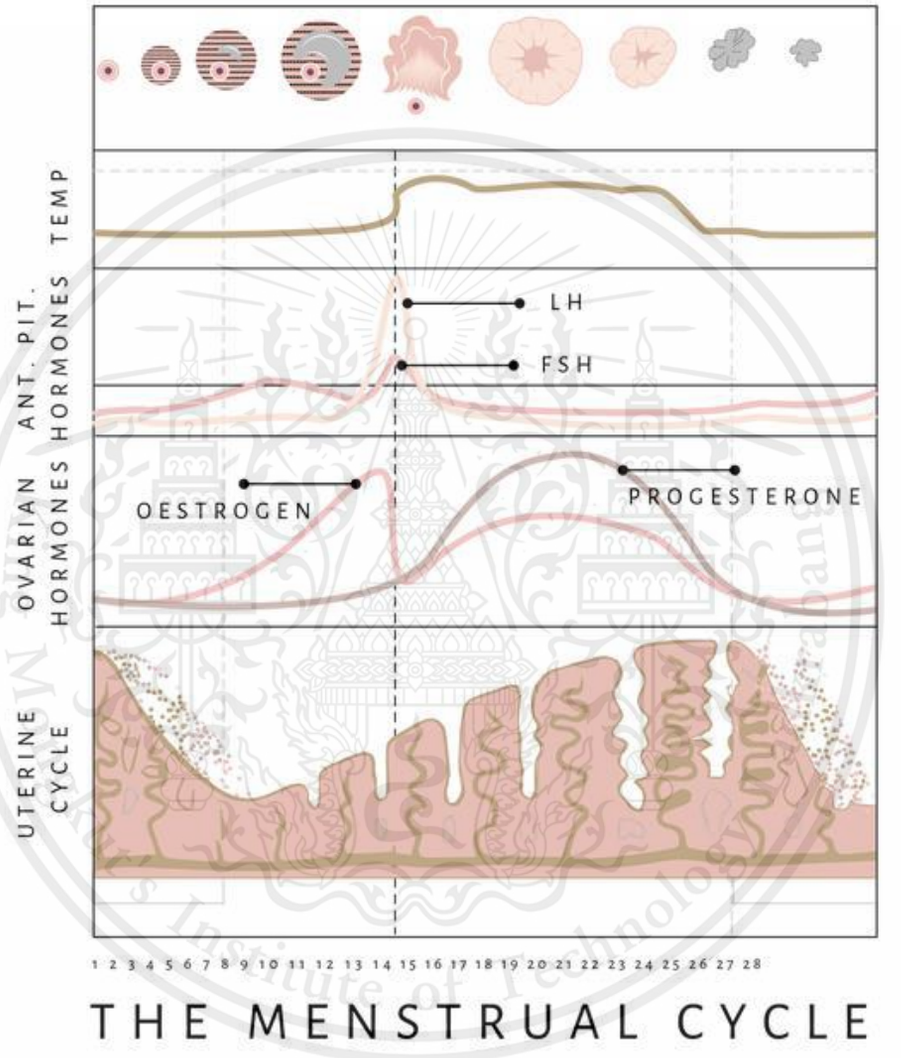

Figure 2.4 The cycle of the menstrual cycle [58].

Pregnancy is where the fertilized egg is implanted, as shown in Figure 2.5, and develops into an embryo until it grows into a baby.

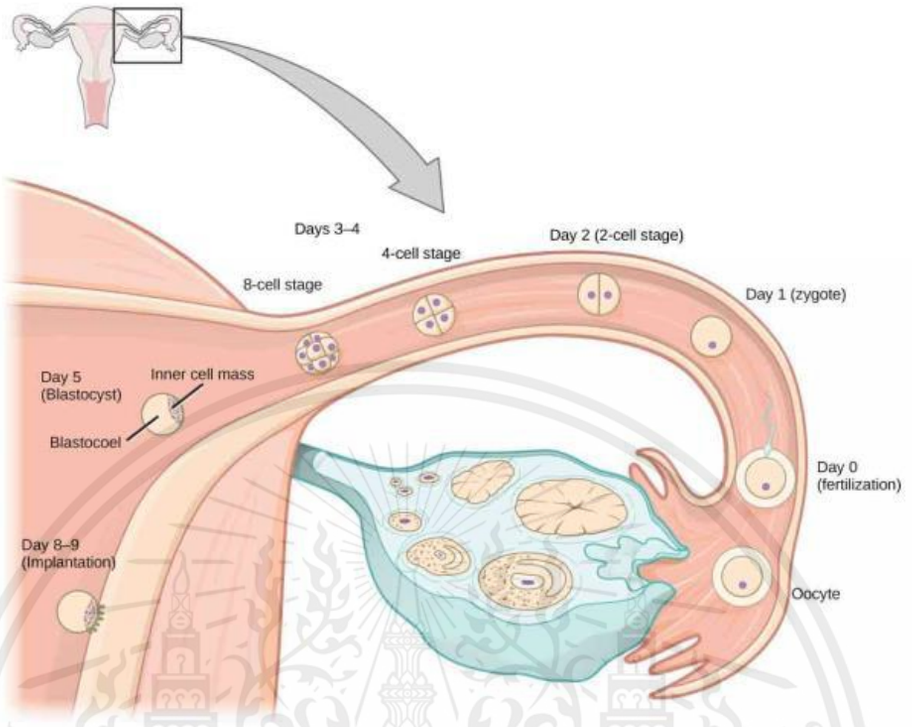

Figure 2.5 The fertilization process that will induce a pregnancy [41].

Birth is due to the maturity of the fetus. During delivery, the uterine wall is contracted periodically to allow the baby to wave through the vagina [5], as shown in Figure 2.6.

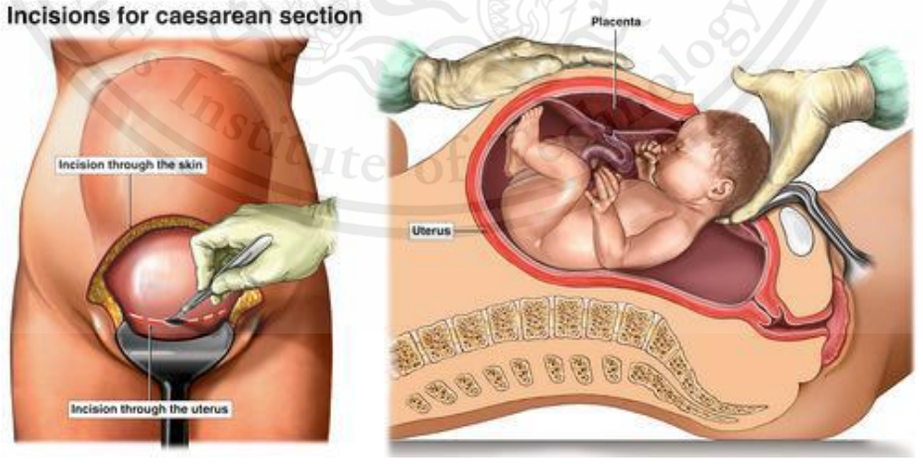

Figure 2.6 a pattern for giving birth [5].

2.2.2 Uterine components

The uterus consists of 3 different parts:

2.2.2.1 Body and Fundus

It is the most common area and is the place for the baby to grow inside the womb before pregnancy or ovulation. There will be a change in the dilated uterine wall in preparation to accept the fertilized egg. If the egg is not fertilized, the uterine wall will gradually deteriorate and compress to expel the build-up and bleeding. This hemorrhage appears every 28 days or every month, so it is called “menstruation.” Menstruation cleans the inside of the uterus, and all of the dirt is washed out simultaneously. If not kept clean, it can quickly become inflamed and infectious.

Using sanitary pads to prevent menstruation is good, but it is best to change them and clean them right away. It is going through the uterus into the abdomen. It stimulates the body to create fibers covering the outside, causing the uterus to be covered with these fibers and become thicker, called fibroids. The uterus cannot expand, it can easily cause fibroids or cancer, and during menstruation, there is a lot of pain in the uterus.

2.2.2.2 Uterine tube

It is the upper part that looks like a narrow and long tube. It is located on each side, like a buffalo horn used to receive an egg from the ovary and through the egg to the uterus. Besides, germs or impurities may pass from the vagina, along with the uterus, uterus, and efficiently into the abdomen in the same way.

2.2.2.3 cervix

It is the passage of menstrual blood, which comes from the uterus and flows outward through the vagina. During sex, semen goes into the vagina and goes into the uterus through the cervix. When your egg is fertilized, a woman causes a baby to live in the uterus and come out through the vagina at maturity.

2.3 Cervix

It is part of the uterus and internal reproductive system that extends into the vagina. The cervix is approximately 2 cm in length. Cervix is divided into two parts:

1. Ectocervix is the outer part is smooth, white, and pink skin, lined with flat cells (Squamous).
2. Endocervix is a hole in the middle, covered with red-pink, velvet-like tissue covered with columnar cells, secrete mucus.

The boundary area between the inner cervix and the inner cervix is known as the Transition Zone, where cervical cancer usually begins.

2.3.1 Type of cervical mucosa

There are three types of normal cervical mucosa: squamous epithelium, columnar epithelium, and metaplastic squamous epithelium. You can see it in Figure 2.7 when there is a transformation of the cells in the columnar mucosa into the genus' cells. The junction between the new squamosal membrane and the upper columnar mucosa is called the new squamocolumnar junction (new SCJ). The area or area between the original and the new junction is the transformation zone: lesions within the transformation zone appear in this area. Examination of the cervix by colposcopy so this area must be carefully examined [60].

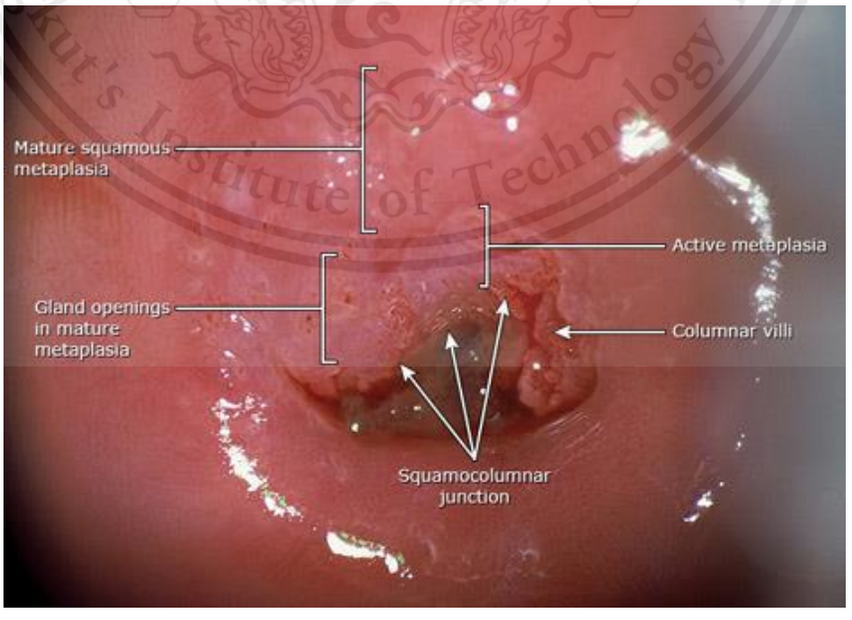

Figure 2.7 A real picture of the cervix [60].

Squamous metaplasia of the columnar endothelial cells in this squamous cell's mucous membranes, as shown in Figure 2.8. Some areas have been fully processed, but others are still in different stages of the process, leaving patches of columnar membranes remaining and surrounded by processed squamous epithelium. If the columnar epithelium has an opening in the skin, mucus will be released through these small openings called "gland openings." Suppose the squamous epithelium covers the cyst. In that case, the mucus has no exit, forming a small cyst called the nabothian cyst. Both the gland opening and the nabothian cyst signify that this area, originally the nabothian cyst's membranes, was formed [60].

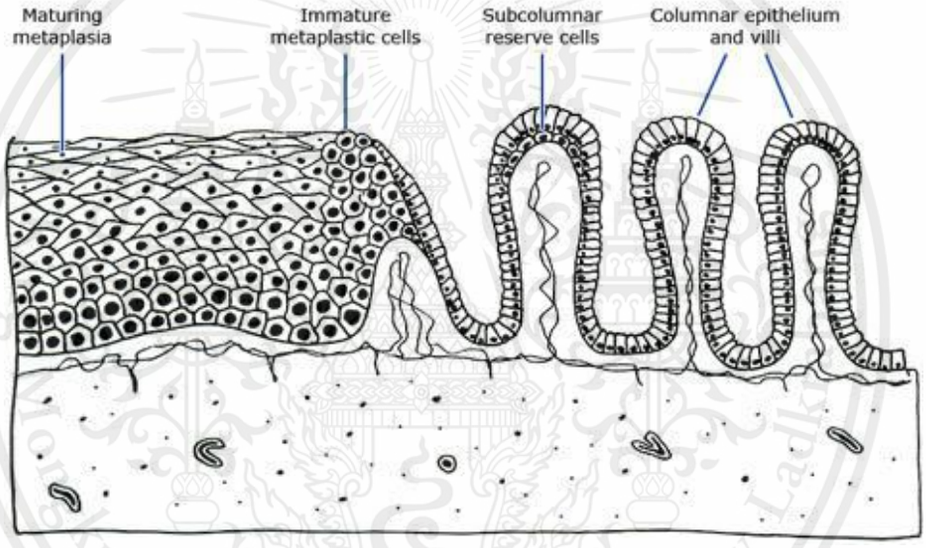

Figure 2.8 Tissue on the surface of the cervix [60].

2.3.2 The importance of the cervix

- Cervical lining contains mucous glands to moisturize and lubricate the cervix.
- During the menstrual cycle, the mucus becomes thick and sticky so that it does not allow sperm to pass through. Still, when the ovulation is ready to be fertilized, the mucus will turn clear, allowing the sperm to pass through the cervix into the uterus.
- Help support the baby during pregnancy, reduce the chance of miscarriage.
- It is the passage of the period.
- During childbirth, the cervix is enlarged to allow the child to come out.

2.3.3 The appearance of abnormal cervical mucosa

Abnormal cervical mucosa is the transformation of columnar endothelial cells. This natural occurrence occurs when a woman enters adolescence, producing estrogen from the ovaries, causing the vagina to become acidic. The columnar mucosa has to be adapted to form the mucous membranes to withstand vaginal acidosis. Suppose a carcinogenic substance such as HPV is involved during this cell transformation. In that case, it will transform into an abnormal squamous cell in the mucosa, so this area is called the atypical transformation zone. Untreated, it may continue in metastatic cancer. Cervical cancer usually occurs in this transformed cell zone. Cancer born outside this zone is sporadic.

The abnormal mucosa has a higher nucleus density and a more massive nucleus size. When exposed to acetic acid, it causes osmolarity changes, resulting in the gaps' osmotic pressure. The cell chest rises, causing water to leak out of the cell and the atrophy of the cell membrane to surround the nucleus. It causes the colposcope's beam to be impermeable, thus seeing a solid white, characteristic dull-white lining after being impregnated with acetic acid. The colposcopy term is called act white epithelium, which can be seen in Figures 2.9 and 2.10. This process takes 1-2 minutes. When the acetic acid seeps out of the tissue and becomes inactive, the water re-enters the cell, the membrane expands, and the whiteness disappears. This phenomenon is temporary only. If the test is needed again, it can be re-impressed with acetic acid. The lesion's severity depends on the mucosa's degree of whiteness (color tone). With duller white, more rigor, the longer the membranes' onset & duration to turn white (onset & time), the higher the lesion's severity. And the edges or joints with normal tissue that surround the margin make it sharper, more severe. If rolling or peeling, the severity of the disease is also greater. Therefore, while the cervix is anointed with acetic acid, it is necessary to wait 1-2 minutes to observe the changes before assessing the lesion's severity.

White mucosa from acetic acid is the most common abnormality in the abnormally processed cell zone, causing the skin to be smooth, veins not visible, and not visible to the naked eye, but it will be visible after impregnation with acetic acid. If the abnormality is more severe, these cells produce tumor angiogenesis factors to allow blood vessels to nourish the lining, thus called detections based on their nature. If the capillaries are inserted through the mucosa on the skin, a red spot at the end of the vein

is known as punctation when examined with a colposcope. If the capillaries are branched like baskets or honeycomb between the lining cells when examined with the colposcope, the veins are lined up like tiles, called mosaic. And if the blood vessels branch abnormally in the plane on the mucosa or near the epithelial surface and grow with strange branching, this is called atypical vessels [60].

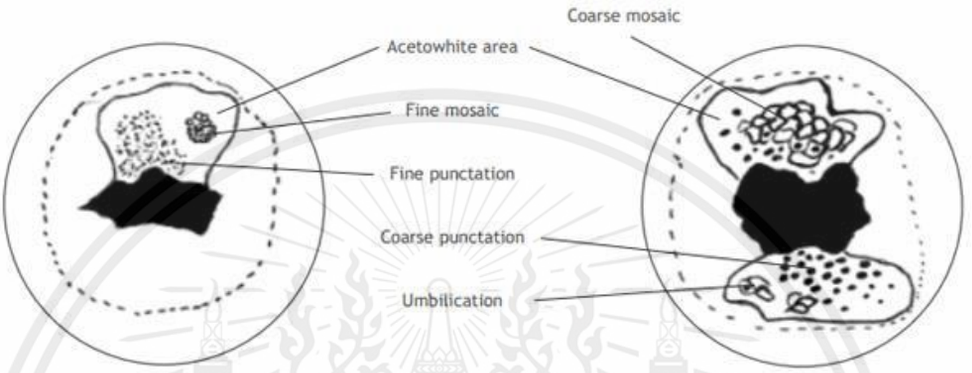

Figure 2.9 The examination of the cervical mucosa by colposcope [60].

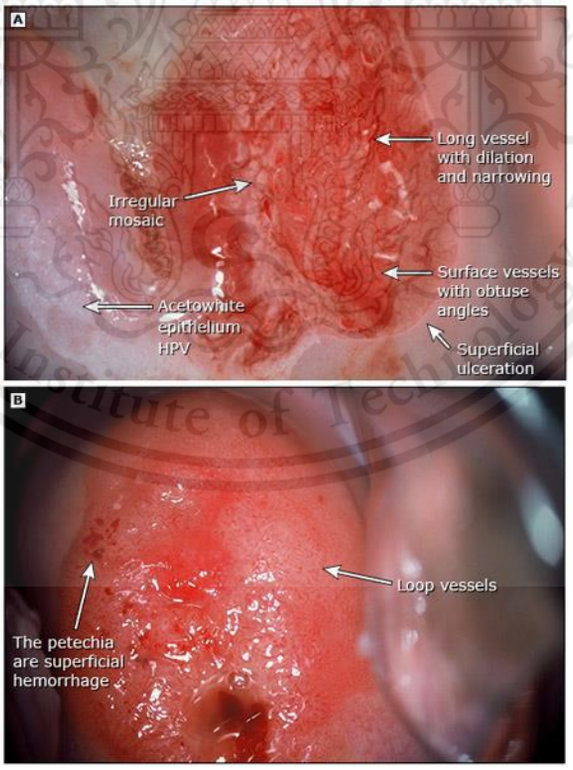

Figure 2.10 Actual picture shows cervical mucosal examinations by colposcopy [60].

The white lesion is seen to the naked eye on the cervical mucosa before impregnation with acetic acid known as leukoplakia or keratosis that are often bounded clearly. As the lining contains keratin, it is opaque and white. It may obscure the underlying blood vessel, making it impossible to diagnose the underlying lining. The importance of leukoplakia depends on where it was born.

If it is contained within the mucous membranes, it is usually less significant, possibly due to injury, irritation, or chronic inflammation and HPV infection.

If inside the transformed cell zone and surrounded by acetowhite epithelium, punctuation, or mosaic, they are essential, not in the leukoplakia area, but on the underlying and neighboring membranes.

The transformed cell region is considered abnormal when it detects: White lining from acetic acid, punctuation, mosaic, irregular veins, and white blemish. These detections can occur alone, or they can be in one location or several. But often can be seen separated from the normal tissues around it. Other conditions that cause cells to divide or build more blood vessels that allow these abnormalities to be seen in the transformed cell zone include infection, inflammation, tissue regeneration, epithelial repair, and metabolic syndrome. Pregnant, etc. [60].

2.3.4 Diagnosis of cells that are expected to be transformed

After impregnated with acetic acid, this metaplastic squamous epithelium is whiter than the original squamous epithelium, with smooth surfaces and tongue-like shapes of various sizes. The transformed squamous membranes can be diagnosed separately from the white lining of the lesion within the scaly membrane by:

- The transformed squamous epithelium will be very white on the new joint and will gradually fade away. The boundary between the transformed Quest and the original Quest is not clear.
- There are often many transformed quest liners. Tongue-like shape Inside, there are round holes, different sizes of the transparent yellow nabothian cyst can be seen. The squamous epithelium covering this tiny cyst is thin and translucent so that you can see the blood vessels under the lining.

The blood vessels that nourish this transformed cell zone There may be many abnormalities, as shown in Figure 2.11, but if you observe. It can be seen that these blood vessels are branching, regular, and not large [60].

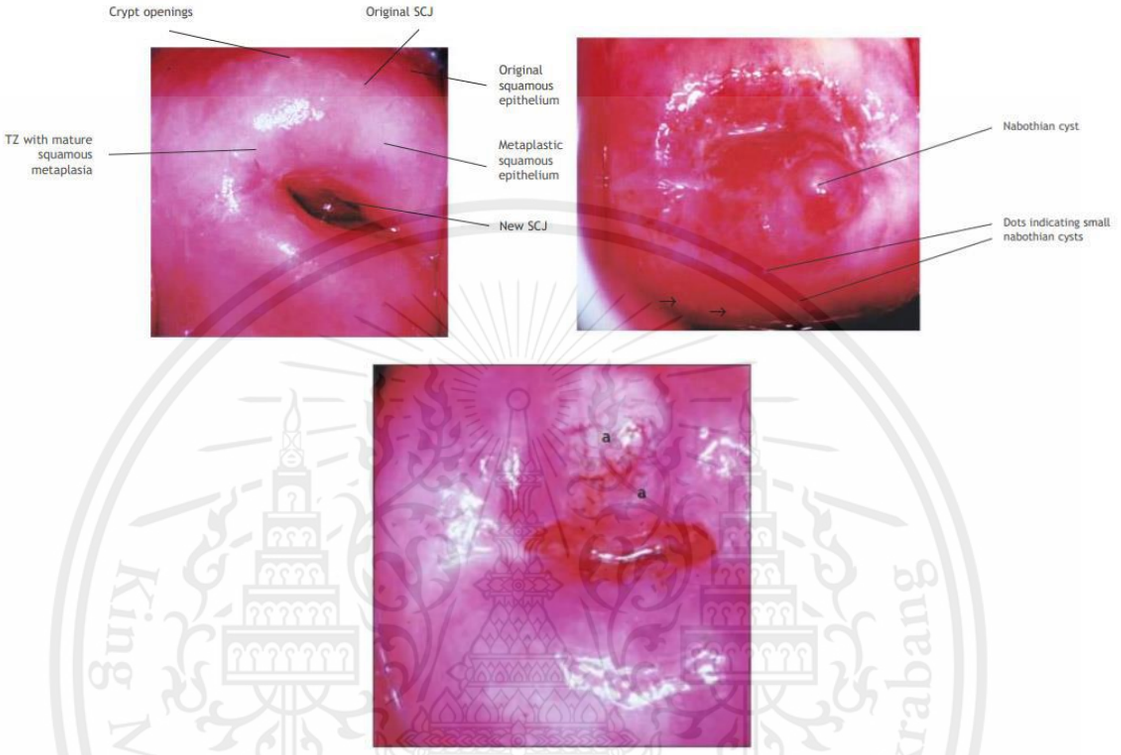

Figure 2.11 Abnormalities on the cervix [60].

2.4 Cervical cancer

Cervical cancer occurs in women's cervix, which indicates a very unusual discharge, purulent-like discharge, abnormal vaginal bleeding other than menstrual blood, bleeding after sex, or those in the golden age that bleeding after menopause. It generally does not have experience symptoms in the early stages of the illness. But it will have symptoms when the cancer cells have spread [21].

Cancer is an uncontrolled growth of abnormally dividing cells or cells that mutate into a malignant tumor spread through the body's organs through the blood and lymphatic systems. Cervical cancer is abnormal cells in the cervix, the innermost part of the vagina, the connection between the vagina and the uterus, and the passage of menstrual blood. Cervical cancer will spread from the cervical area, as shown in Figure 2.12.

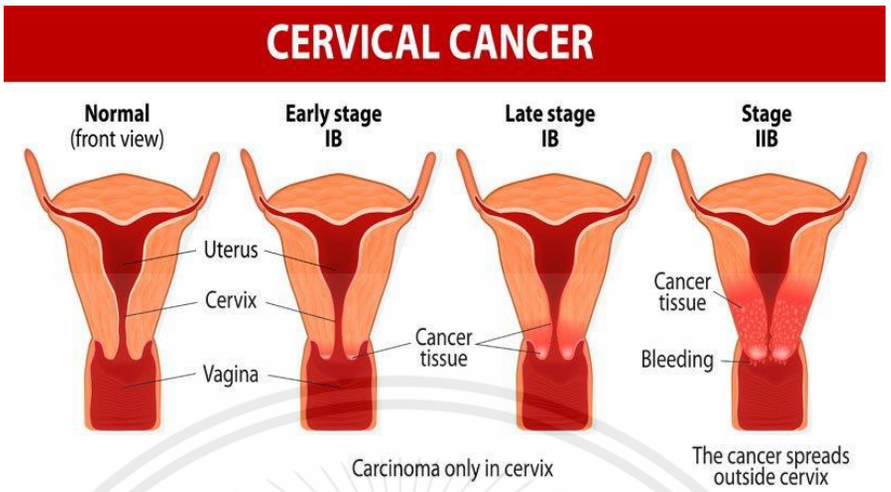

Figure 2.12 The progression of cervical cancer [48].

Reliable statistics in the last year discussing the Non-Communicable Diseases (NCD) mortality rate in all age groups. It was found that the number of deaths from cervical cancer was around 600 in 1 hundred thousand, making it the fourth higher than the cancer death group, followed by liver, lung, and breast cancer. It was ranked second in cancer mortality in women after breast cancer. Cervical cancer is one of the deadly diseases. If left untreated and the infection spreads, it is a silent threat for women who continuously monitor and check their health [48].

2.4.1 Causes of Cervical Cancer

Over 99% of cervical cancer is caused by HPV infection through sexual intercourse. Other potential risk factors may cause cervical cancer, such as cell changes in pre-uterine cancer (Cervical Intraepithelial Neoplasia (CIN) stage), Low immunity, smoking, and having multiple children.

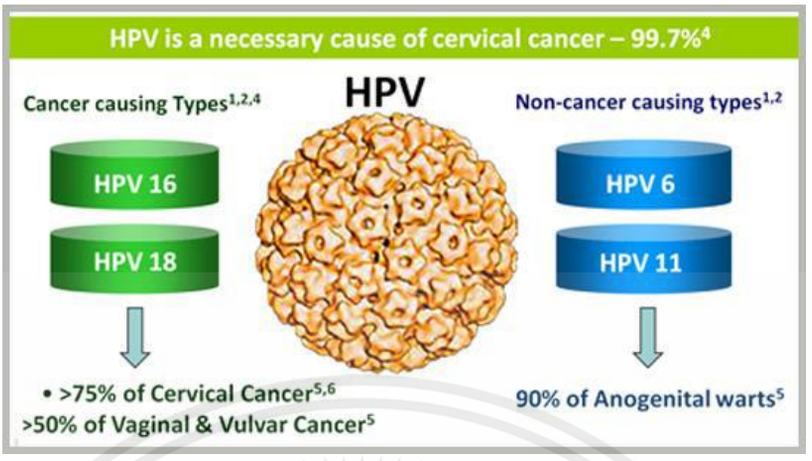

Figure 2.13 The leading causes of cervical cancer [24].

2.4.2 Symptoms of cervical cancer

Signs of the disease usually arise when cancer has already spread to the stage. There will be symptoms, as shown in Figure 2.14, such as abnormal vaginal bleeding, bleeding during intercourse (which has never happened before), bloody or pus-filled vaginal discharge, vaginal discharge. It has an unusual smell of pain in the vagina during sex. Other symptoms may arise if cancer cells have spread to other organ tissues, such as loss of appetite, weight loss, bloody urine, bone pain in various areas, etc. If suspicious symptoms are found, as mentioned above, the patient must seek immediate medical attention [21],[53].

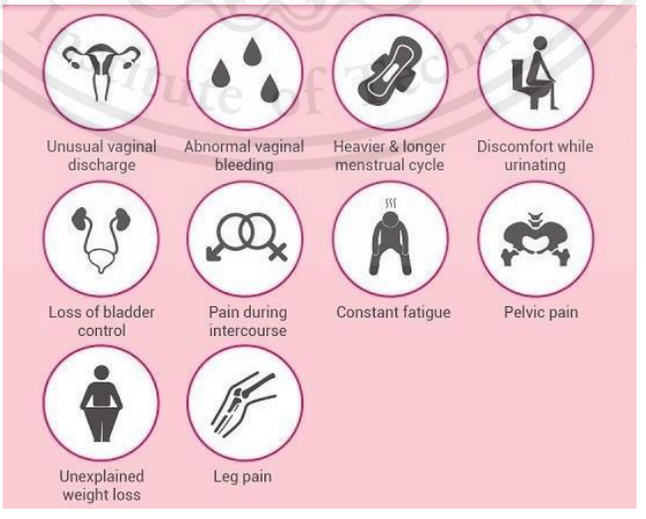

Figure 2.14 Symptoms of cervical cancer [53].

2.4.3 Cervical cancer treatment

The treating cervical cancer procedure depends on the symptoms and stages of the disease. Before receiving any treatment, the doctor and the patient must discuss and decide together about the pros and cons of treatment, effects, and complications. After treatment, the treatment type choice is based on the illness's length, the likelihood, and the treatment success percentage [21].

Treatment methods used in the pre-cancer stage are surgery or partial treatment of the cervical lesions, Large Loop Excision of the Transformation Zone, Cone Biopsy, Laser Therapy, and follow-up appointments.

In patients with cancer cells detected, treatment is required according to the stages and symptoms they are experiencing. In some cases, there may be complications from cancer spreading through different parts and may use a combination of treatments more than one method by the doctor will consider the suitability of the physical condition and the illness.

The treatment methods used in patients already diagnosed with cancer are radiotherapy, chemotherapy, cervical surgery, uterus, and ovaries, depending on their suitability according to their severity and the organ where cancer has spread. Most of the time, early-stage cancer patients will use surgical treatment and chemotherapy. Patients with advanced cancer progression often use radiation therapy in combination with chemotherapy [21].

2.4.4 Complications of cervical cancer

Suppose cancer begins to spread to nearby tissues and organs, including the bones, liver, lungs, and brain. It will affect the internal organs system, causing various ailments expressed by conditions that may arise after the illness, with cervical cancer, including pain in the body. Where cancer may have bleeding disorders, such as bleeding from the vagina or in urine, the vagina has an unpleasant odor and infection in the vagina, the formation of blood clots that may block the bloodstream, the perforation between the organ tissues resulting in fluid from the vagina, and kidney failure. Due to diffuse cancer, blood may grow and block the ureter, causing the renal system to fail to function normally and, eventually, kidney failure. Besides, complications can occur after chemotherapy, radiotherapy, or surgery.

2.4.5 Cervical cancer prevention

How to prevent and reduce the risk of cervical cancer. It can be done by

- HPV vaccination can protect against certain strains of this virus, including high-risk strains like the HPV-16 And HPV-18, to reduce the risk of self-infection HPV by approximately 90-100% in people who have never been infected. This vaccine can be injected from 9 to 26 years.

- Protection during sex: Use a condom to prevent contact and not to change sexual partners frequently.

- Do not smoke, take care of your health, and check your health regularly.

- Periodic screening with cervical cancer screening and seek medical attention if signs of suspected disease are found to prevent cervical cancer. Or to know the stage of the illness and receive treatment from the beginning before cancer spreads.

2.4.6 Cervical cancer screening

There are several methods of screening for cervical cancer, including:

2.4.6.1 Cytological examination or Pap smear test

Your doctor will perform a physical exam, internal exam, and screen for abnormal cervical cells. With cytological examination (Pap smear), as shown in Figure 2.15, which is a complete examination of the cervical cells. That there are abnormal cell changes or not. Sometimes the abnormal results of that cell may not always be cancerous. Doctors will diagnose by colonoscopy with other tests such as CT scan, MRI scan, chest x-ray, blood test, or Complete Blood Count (CBC) to assess whether the cancer is in any stage and help plan the next treatment.

Figure 2.15 A simulation of a cervical cancer diagnosis [13].

The indications for a cytological examination or Pap smear test are as follows:

- Women who have had vaginal intercourse with men (no matter how young they are), counting the time since then, have passed three years before the first cytological examination is required.
- Women who have reached 21 years of age, single (never had sex), have a husband or have had a sexual partner need to have their first cytological examination.
- Women aged 21-29 years should have a cytology examination every three years if the latest test results are normal (Negative).
- Women aged 30-65 should have a cytology test in conjunction with an HPV test every five years if the test results are normal (Negative) because the chances of getting cancer in the next five years will be rare. Therefore, the examination can be waived for 3-5 years (but if only Pap Smear is checked every three years).
- Women at high risk of cervical cancer, such as having HPV infection, Human Immunodeficiency Virus (HIV) infection, or having a sex partner infected by a Sexually Transmitted Disease (STD) such as Syphilis, gonorrhea, etc., having low immunity (e.g., From organ transplantation, chemotherapy, other cancer) and Diethylstilbestrol (DES) to prevent miscarriages, having mothers using this drug while pregnant (very rare today) that Pregnant and giving birth while infected with HPV which being a cigarette addict, having sex for the first time at a young age (before 18), having or having had multiple sex partners, having had sex since Young age with various boyfriends, family history of cervical cancer, or previously diagnosed or at risk of cervical cancer. It may need to be checked more frequently, as advised by your doctor. The doctor may recommend a cytology test twice a year for the first year, after which it may be every three months, six months, or one year depending on the results and the doctor's discretion for as long as they are in good health.
- Women aged 65 years and over who have had a regular cytological examination in the past ten years or the last three consecutive examinations have been normal (Negative) every time. In such cases, doctors are advised to discontinue

cytology or Pap smear test for the rest of their life (women who stop screening should continue to receive preventive healthcare).

- Women who have had complete removal of the cervix during a hysterectomy to treat non-cancerous diseases such as uterine fibroids. In this case, your doctor may terminate the cytological examination or Pap smear test for the rest of your life (but if your cervix is still left, cervical screening will need to be screened typically, just like most women).

The cytological examination or Pap smear test procedures are as follows:

The test is not as painful as you think, which is very easy to do and takes about 10-15 minutes to complete, but it is important to relax so that you do not cause any stiffness during the test, as this will help. It does not hurt and allows the doctor to examine easier and faster, in which the examination process is as follows.

1. Cytology examination is conducted in an outpatient examination room, which is a relatively closed room. The test will not use any medication before the test. Once you have decided to do the exam, the staff will guide you to urinate and change your clothes to take off your and wears a sarong. It looks like a sarong that the hospital has provided. If you wear a skirt that does not seem very narrow or short, you can simply remove your panties without wearing a hospital bag, and you can go to the examination bed.

2. After changing the clothes, the staff will invite you to lie on your back on the visceral examination bed, which will look like a trestle supporting both legs to separate the legs.

3. The staff will open the sarong, cover the cloth, and leave enough space for the examination. After that, the team will call a doctor for an examination.

4. When you are ready, the doctor who is wearing gloves will clean the area with an antiseptic. Use a speculum, which looks like a platypus, inserted through and extending the vagina, as shown in Figure 2.16, to see the cervix. During this tool's insertion into the vagina, you should keep your knees as complete as possible while trying to lay your bottom on the bed. It will reduce the muscles' stiffness in the vagina, make it less painful and make it easier for your doctor to insert the device (sometimes your doctor may tell you to push a little to make it easier to insert the device). However, this process can be a bit uncomfortable and may cause a little pain in some, but do not

worry. Doctor will select the right size for each person's vagina, including in women who have never had sex as well.

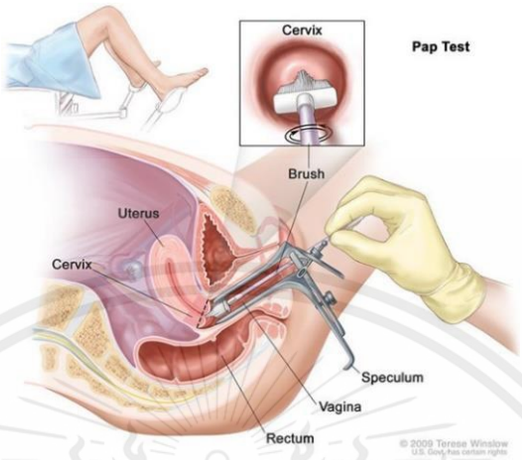

Figure 2.16 The use of a vaginal speculum for cytological examination [10].

5. When the doctor can insert the instrument in the appropriate position, i.e., the cervix's opening has already been seen. The doctor will use a device that looks like an ice cream stick but is much smaller or uses a small brush to smear the cells around the cervix (if it is a simple cytology test) [10]. The doctor will put the compartment that holds the cells onto a slide and soak it in an alcohol solution as shown in Figure 2.17. But if it is a thin sheet cytology examination, the doctor will take a cell-collecting brush and dip it into a vial containing a unique solution). The result will show whether abnormal cells are compatible with the pre-cancerous stage or cervical cancer stage before rushing to the laboratory for further pathological analysis [21]. It must take time to wait for about 1-4 weeks [14].

Figure 2.17 Cell collection in the cytological examination [14].

After the cell collection is complete, the doctor will remove the cell collection device. A speculum followed them to expand the vagina out of the vagina. At this point, the cytological examination has ended. The doctor may then perform a pelvic exam with the right hand's index and middle fingers inserted into the vagina. The left hand is palpated on the lower abdomen simultaneously, as shown in Figure 2.18, to find abnormalities in size, shape, position, and color of various internal pelvic organs [21],[30]. In the meantime, try to relax a lot and do not strain your stomach. Because it allows doctors to easily, accurately, and quickly complete the exam. After that, you can get off the examination bed and change back into the same suit. (The internal examination is usually done in conjunction with the cytological examination or Pap smear test. If you need a cytology examination, your doctor will do a cytology exam first, then an internal examination).

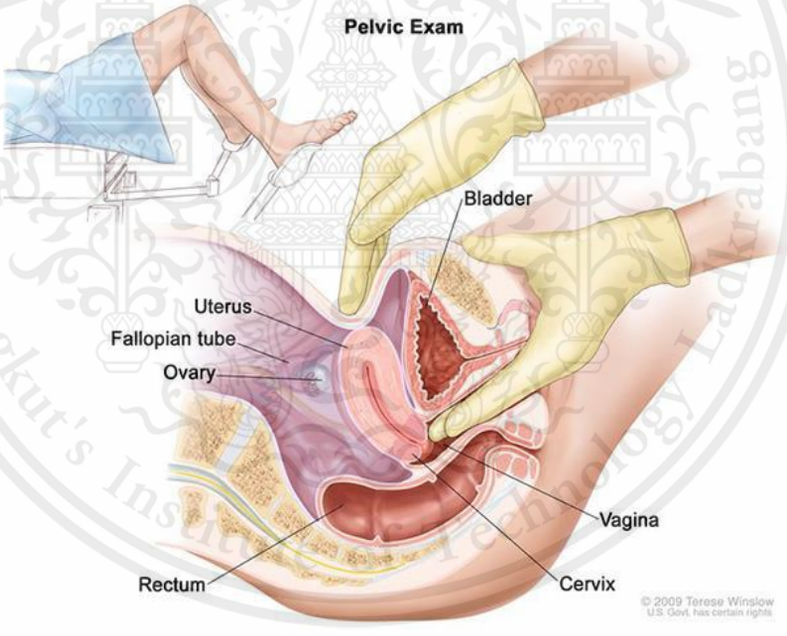

Figure 2.18 A simulation of internal examination [30].

Usually, both the cytological exam and the pelvic exam will not cause any pain. The test recipient does not have to worry. Still, sometimes the test can cause minor side effects such as pain, little diarrhea. Or pain in the uterus occurs immediately after the examination or appears while the doctor examines and collects cervical cells. But in general, it is rare, or if it does, it is usually temporary. Once the test is complete,

symptoms will disappear or be quick for a short time (if the symptoms are very disturbing, pain medication can be taken). Besides, some women may bleed after the test. But often, a little blood and disappear within a day, but there is a lot of bleeding. If the pain persists or the abdominal pain persists, consult a doctor.

2.4.6.2 Liquid-based Cytology

It is a laboratory method using specialized equipment to collect samples by marking the epithelium from the cervical area in the same way as the Pap smear. All collected sample cells are placed in a vial to treat cells and sent to an automated machine for epithelial cell preparation [40].

2.4.6.3 HPV-DNA detection

It is the direct detection of the Deoxyribonucleic acid (DNA) of the HPV virus [30]. This method has a very high sensitivity to detect cervical abnormalities but is still expensive than other tests.

2.4.6.4 Colposcopy

It is an instrument used to examine and look at the details of cervical lesions. To diagnose the disorders that occur accurately and precisely.

2.5 Colposcopy

Colposcopy is a minor procedure which using a special microscope to examine the surface of the cervix for abnormalities. Gynecologists use colposcope, which looks like a pair of binoculars with a lighting instrument that allows them a greatly magnified view of the surface of the vagina and cervix. If an area needs further investigation, the gynecologist can remove a tiny piece of tissue and send it to a laboratory for a biopsy. Colposcopy is often done if cervical screening (Pap smear test) shows result of abnormal cells in cervix as shown in Figure 2.19. During a colposcopy, a tiny piece of tissue might be removed and sent to a laboratory for histopathology. A colposcopy can substantiate whether cells in the cervix are abnormal and determine whether patient need treatment to remove them [32].

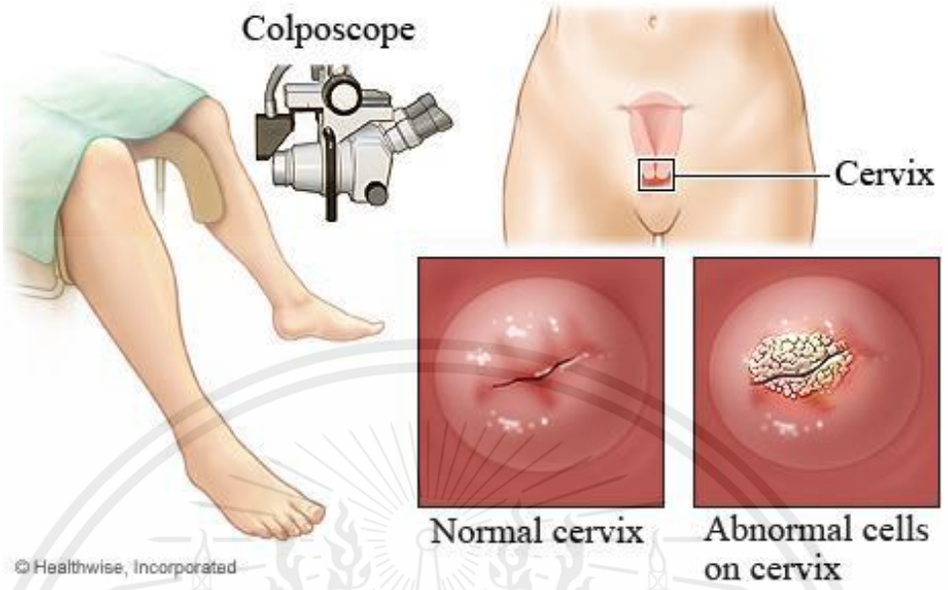

Figure 2.19 A simulation of colposcopy [33].

Cases where colposcopy should be performed are as follows:

- Cervical screening results with abnormal cytology (abnormal mucosa that cannot be identified as cancerous (Atypical Squamous Cells of Undetermined Significance (ASC-US)) or more severe). Colposcopy is most commonly recommended.
- Cervical abnormalities such as a wound or a lump from a visual examination.
- Bleeding irregularities during menstrual cycles with unexplained or unexplained bleeding after intercourse and unexplained long-term vaginal discharge or may be examined with colposcopy to rule out cancer.
- Suspicious lesions around the vagina and vulva from a visual examination.
- Persistent HPV infection such as an HPV test and a DNA test yielded two positive results from 12 months apart.
- Visual Inspection with Acetic acid (VIA), white or abnormal blemishes.
- Follow-up examination after treating CIN with topical treatment such as cold cauterization and electric loop cutting, etc.
- Cervical lesions with one abnormal division that persists for more than 12 months.

- The partner has a tumor or genital warts on the lower genitals.
- The cytological examination results revealed multiple instances of idiopathic inflammation, especially in women with risk factors for cervical cancer.

Cases that should avoid colposcopy include:

- Women with heavy menstrual bleeding.
- Cervical, vaginal, or acute or severe cervicitis should be investigated and treated first, as examinations and biopsies may cause bleeding. Painful and uncooperative in the examination. Besides, inflammation may impair the accuracy of the examination.
- Taking anticoagulants of women may need to stop the drug for several days before cervical biopsy or endocervical curettage [32].

As for pregnancy, it is not forbidden from colposcopy, but retrieval may need to be modified, such as avoiding cervical biopsy if the test is not suspected of metastatic cancer and is not. Should be scraping the lining inside the cervix Women after menopause who are not receiving hormone replacement may need to be given estrogen or taken three weeks before the test. Should have sex. Inserting medication or a tampon into the vagina 24 hours before the exam.

The main purpose of colposcopy. If abnormal cytology examination results are found, there are three things which are:

1. To determine that there is no metastatic cervical cancer.
2. To detect advanced lesions such as pathology, cervical mucosa, CIN 2,3, and early cancers on the layer of normal cells have not yet been inserted into normal tissue (adenocarcinoma in situ), requiring treatment not to progress into metastatic cancer.
3. To guide other appropriate care, if the cytology or Pap smear results are abnormal mucosal, abnormalities cannot be identified as cancerous or not (ASC-US), or minor anomalies of uterus cells (Low-grade squamous intraepithelial lesion (LSIL)). And colposcopy, no lesions were found, the pathogenesis could be monitored every six months, or if the cytology results were moderate and severe abnormalities of cervical cells (High-grade squamous

intraepithelial lesion (HSIL)). The results that check with a colposcope, no transformation zone, or can see areas where cells have not changed all or not all lesions should be further diagnostic excision.

When examining the cervix with a colposcope, it will find the mucous membranes that are normal or maybe abnormal, as shown in Figure 2.20, showing parts of the cervix.

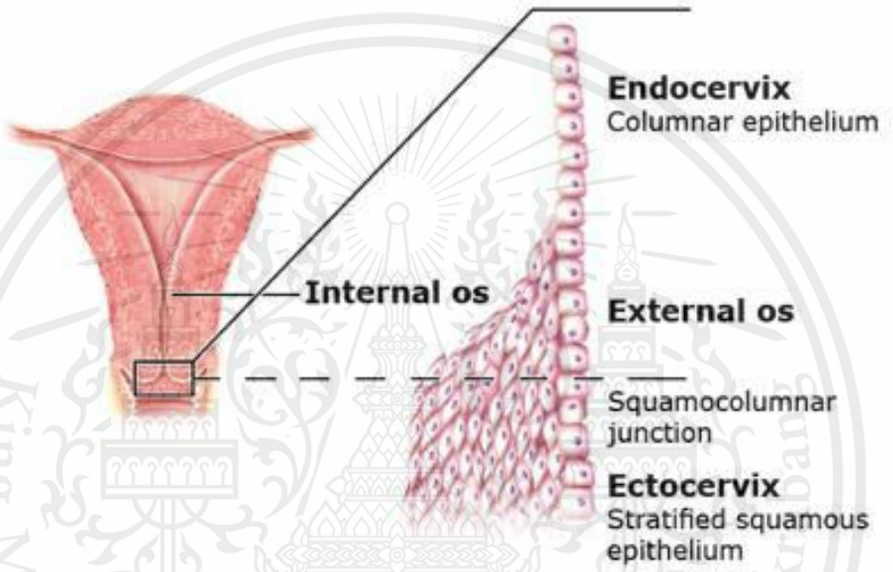

Figure 2.20 Parts of the cervix [60].

2.5.1 Observation of cell changes in colposcopy

Colposcopy examines two changes in the cervix:

Epithelial changes, such as smooth or rough skin, indicate lesion severity, opacity, or whiteness after acetic acid impregnation, indicating cell density or lesion severity: the edge or joint between the lesion nearby mucosa.

- vascular changes, such as the appearance and size of different blood vessels, the spacing between blood vessels, abnormal vascular intensity, and the blood vessels' location within the lesion or lying on the lesion's surface.

The equipment required for cervical examinations by colposcopy are:

- vaginal speculum of different sizes as appropriate for each patient's vagina.

- lateral vaginal wall retractor, used to stretch the lateral vaginal wall to block the cervical examination.
- The hook is used to lift the smooth tissue for more precise excision and pull the vaginal wall to examine the wrinkles.
- The endocervical speculum is used to examine the cervix inside cases where the lesion or the processed cell zone is not deep.
- tissue forceps at least 20 cm long, used to hold a cotton swab moistened with acetic acid to soothe the cervix and hold the gauze to stop the bleeding.
- punch biopsy forceps. The cutting tip must be sharp so as not to scrape the epithelium. The handle must be approximately 20 - 25 cm long to be able to cut in depth.
- endocervical curet for scraping the lining inside the cervix for pathological examination. The tip of the instrument must be sharp and small enough to fit inside a short cervix. Some use the endocervical brush to collect sample cells inside the cervix for cytological examination or Pap smear test.
- cervical gripping apparatus such as a tenaculum or allis Clamps are used to hold the cervix so that it does not escape during a biopsy or while scraping the cervix. It is generally not required and can cause bleeding at the fangs of the instrument.
- Cotton gauze with gauze or vaginal packing gauze is used to stop bleeding from the cervix after excision.
- A cotton ball or cotton swab is used to moisten the acetic acid solution, soak the cervix, wipe the blood, and press the bleeding points before being charged with gauze.
- 3-5% acetic acid solution may be placed in a vial with a nozzle to inject the cervix when examining the cervix for changes in the mucous surface.
- Normal saline solution for cleaning the cervix.
- Iodine solutions such as Lugol solution or Schiller solution for Schiller. Test to detect colored and non-stained areas of iodine, crystals, or silver nitrate stick and Monsel solution for the hematoma to stop bleeding. Some people do not prefer to use silver nitrate because it produces silvery sediment that interferes with the next colposcopy exam. In general, a long cervical charge with a long

gauze is sufficient to stop the bleeding at the site where the biopsy can be examined.

- A device for collecting tissue samples from biopsy: a vial of formalin, a toothpick for pushing tissue out of a biopsy forceps.
- Equipment for cytological examination, including Ayre spatula, glass plates, cell fixative bottles.
- There is an examination result sheet and a post-examination advice sheet.

2.6 Complementary Metal-Oxide Semiconductor (CMOS)

In 1963, The complementary metal-oxide-semiconductor (CMOS) was invented by Frank Wanlass. However, he didn't receive a patent for it until 1967, and it failed to become widely used for imaging applications until the 1990s. During a CMOS sensor that's an electronic chip that converts photons to electrons for digital processing, the photosensitive pixel's charge is converted to a voltage at the pixel site. The signal is multiplexed by row and column to multiple on-chip digital-to-analog converters system (DACs). CMOS sensors create images in digital cameras, digital video cameras, and digital closed-circuit television (CCTV) cameras. CMOS may be found in astronomical telescopes, scanners, and barcode readers. The optical technology is employed in machine vision for robots, in optical character recognition (OCR), within the processing of satellite photographs, and therefore the enhancement of radar images, especially for meteorology. Inherent to its design, CMOS could be a digital device. Each site is three transistors and a photodiode that performing the functions of activating or resetting the pixel, selection or multiplexing, and amplification and charge conversion as shown in Figure 2.21. Because of fabrication inconsistencies within the multiple charges to voltage conversion circuits, the results is the high speed of CMOS sensors and high fixed-pattern noise and low sensitivity [8],[45].

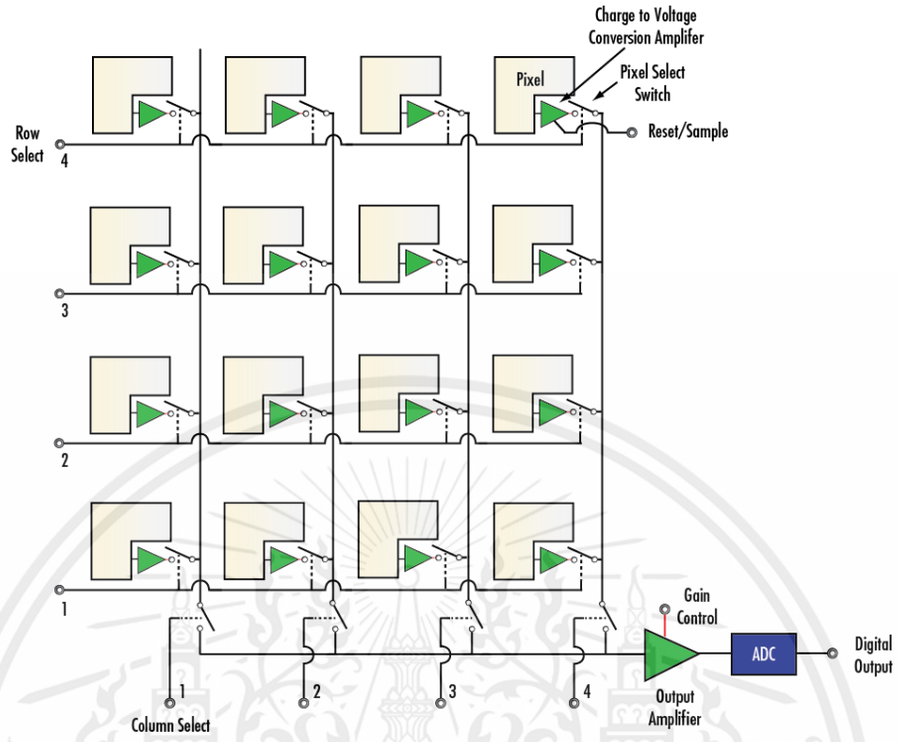

Figure 2.21 The diagram of a CMOS [8].

The CMOS's low manufacturing cost makes it possible to make low-cost consumer devices. Advances of CMOS technology have made it possible for them to approach their competitor in high-end digital cameras and charge-coupled devices (CCD). In contrast to CMOS, CCD cells aren't surrounded by transistors and must actively use power to collect light. It makes them less power-efficient but also enables the advantages of a lower-noise image and greater light sensitivity [8].

2.7 3D Imaging system

Stereoscopy or stereoscopic imaging, or 3D imaging, is a technique for creating illusions from photos or movies on a flat two-dimensional plane to see the illusion of depth. Making the viewer see a 3D image makes each viewer see the image with different views by taking two pictures of the same object at a slightly different angle. And using one of the 3D viewing techniques to send each image to both eyes, resulting in the brain interpreting it as a deep image and allows us to see images in a 3-dimensional. These are the way to display 3D images.

2.7.1 Anaglyph 3D

Anaglyph 3D display is an image projection for the left and right eye with different color tones on the same receiving scene. The color scheme used is often red and blue. Looking with bare eyes will result in a slight double and overlapping vision. For visualizing a 3D image, it has to use glasses with a light filter, one in red and the other in blue. This pair of glasses cut out the color that matches the color of the glasses. Where the red glasses will cut the red image, the image is only blue. While the blue glasses will cut out the blue part, making the image only red will allow both eyes to see the image from different angles. Then, the brain will interpret it as if seeing a 3D image [17].

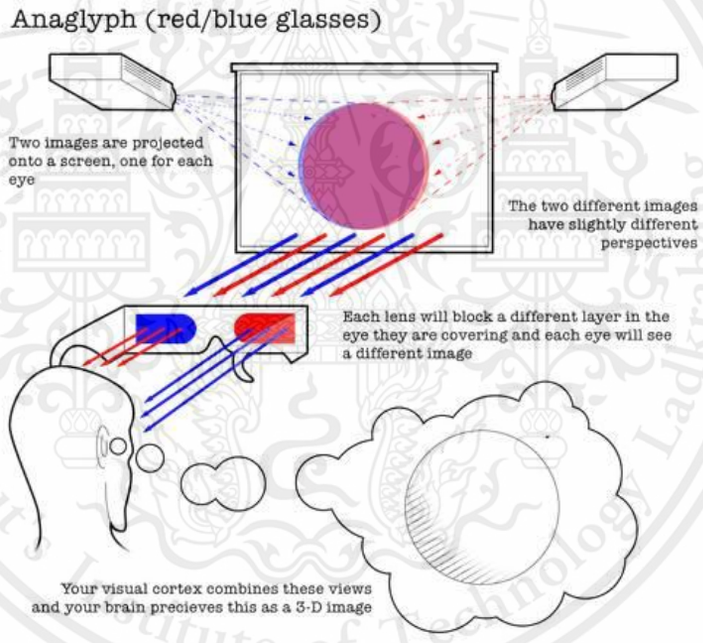

Figure 2.22 Anaglyph 3D diagram [17].

Figure 2.23 Anaglyph image with red and blue color [49].

2.7.2 Polarized 3D

The polarized 3D display operates similarly to the anaglyph 3D by projecting images onto the same receiving scene and having a different perspective. But the switch from using color as a cut-off the filter to use each projected image's viewfinder orientation is overlaid instead. The left eyeglasses see the image through the vertical channel, while the right eyeglasses see the image through the horizontal channel, causing each eye to see the image differently. Polarized glasses are specially used as 3D glasses for viewing polarized images. It will make the picture more realistic and colorful than the anaglyph 3D. So, this technique is commonly used in 3D movies [17].

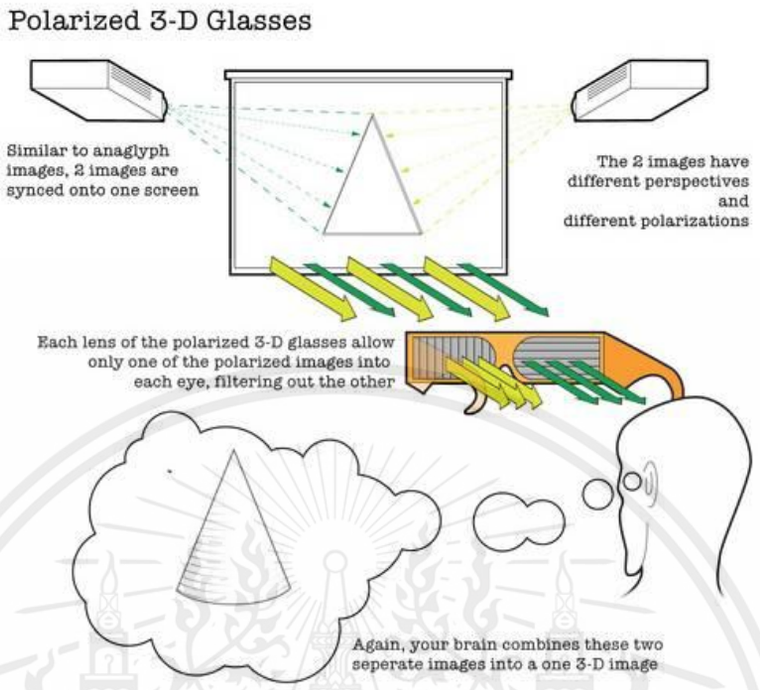

Figure 2.24 Polarized 3D diagram [17].

Figure 2.25 Polarized image [17].

2.7.3 Active Shutter

Active shutter display projects two images with different perspectives by switching between 2 images quickly. It requires a projection with a minimum display frequency of 120 hertz. It is because the image for the left eye and the right eye must be shown alternately. Therefore, the image display will be left-right order, continuously switching to complete 120 images in 1 second. The left and right eyes can see 60 images in 1 second, which is the minimum frequency that does not feel the image shaking. Projections of this type will require active shutter glasses to assist in viewing the image by the glasses communicating with the projector which side to cover [59].

Active Shutter Glasses act like a shutter that quickly switches to close and open the front of the lens, in which the opening and closing of each glasses correspond to the switched image on the screen. The viewer can see the picture for the left eye and the right eye at a very close time. The result is that the viewer sees the image that appears on the screen in 3D [59].

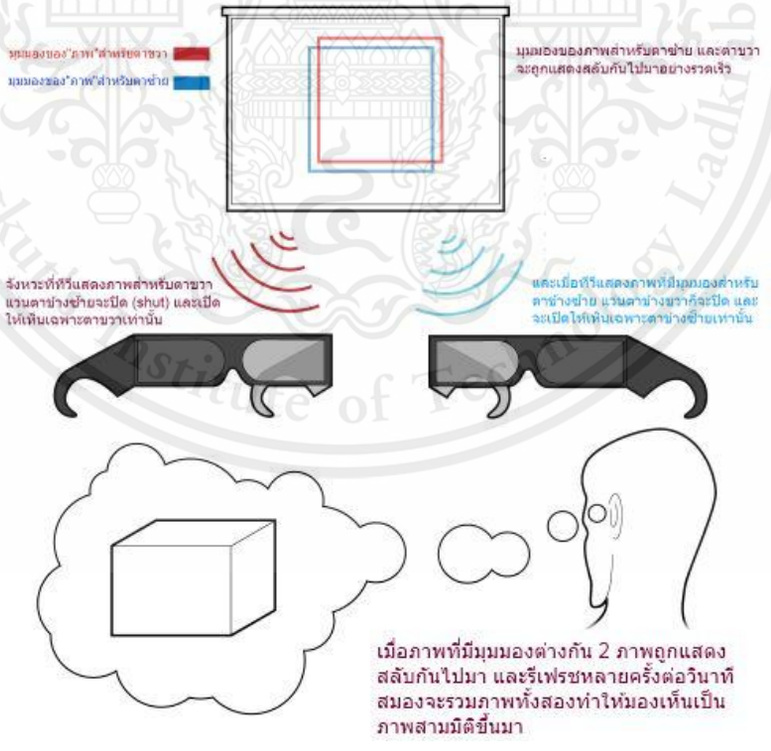

Figure 2.26 Active shutter diagram [59].

2.7.4 Parallax Barrier

Other types of 3D displays require 3D glasses, but the parallax barrier won't use glasses. This method divides images with different camera angles into bars and then places them alternately with a special filter layer, called Parallax Barrier. This filter will divide each eye's image, which looks through this filter shows a different image. The brain then combines these images from the left eye and the right eye with different angles into one image, and we can see it in 3D. In other words, the parallax barrier works instead of glasses that filter both images so that each eye can see the image differently from each other [38].

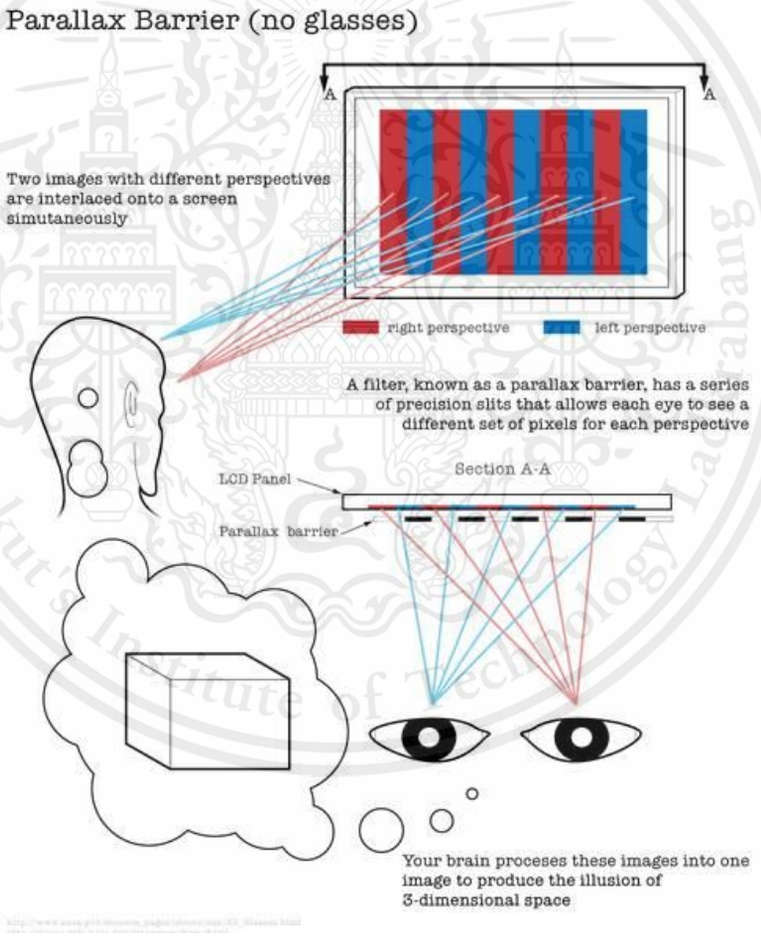

Figure 2.27 Parallax barrier diagram [38].

2.8 Artificial intelligence (AI)

Artificial intelligence (AI) is one of the wide-ranging branches in computer science. It concerned with making intelligent machines which have ability to perform tasks that typically require human intelligence. AI is a multidisciplinary science with various approaches, but furtherance in machine learning and deep learning for creating a paradigm shift in virtually every technology industry sector [3].

AI is a processing system based on the human neural network. They can learn and optimize processing as the number of information increases through a self-learning process. It can quickly recognize, think, analyze, learn and link complex information like a human brain system [37]. Therefore, AI is the most popular technology that plays an essential role in work and life, including enhancing business and industry potential [4].

Artificial intelligence is classified into three levels according to ability or intelligence:

1. Artificial Narrow Intelligence (ANI) or Weak AI: AI with specialized abilities better than humans or good at specialized tasks that have been programmed to do. For example, AI-assisted robotic surgery may be more proficient in surgery than modern doctors. But this AI is not able to cook, sing, or do anything other than surgery [3],[44].
2. Artificial General Intelligence (AGI) or Strong AI: AI with the ability to perform tasks that are equivalent to the human brain, such as being able to think, analyze, plan, and solve complex problems. It can understand abstract stories, including being able to learn from past experiences as humans can [3],[57].
3. Artificial Super intelligence (ASI): AI with superior intelligence than humans, which is currently unable to develop this level of AI. But ASI ideas are often present in media such as games, movies, or novels [44],[57].

AI is generally primarily a field in computer science and engineering. But sometimes, it also includes other fields, such as psychology, philosophy, and bioscience. AI does not have definitive requirements or patterns to determine machine

intelligence because we cannot compare it with the constantly changing human intelligence [37].

AI works by collecting massive volumes of data with speed, repetitive processing through intelligent processing workflows. This processing relies on software that can automatically learn from the patterns and characteristics of data based on a theoretical basis, methods, and technologies:

- Machine learning: It helps to create automated analysis models using methods from neural networks, statistics, operations research, and physics to find insights hidden in the data without the need for programming to find them.
- Neural network: It is one of the machine learning systems, using a link between units (like neurons). It processes data by responding to external data and relaying information to each other between units. Processing requires multiple data passes to find connections and convey meaning from those ambiguous data.
- Deep learning: It uses a large neural network with a multi-layered processor. It relies on advancements in computing capabilities and the technique of learning large-scale complex information that has already been developed.
- Cognitive computing: It is a sub-branch of AI that seeks to express human interaction through machines. The ultimate goal of using AI and memory processing is to use machining to mimic human processes through the ability to interpret images and speech and respond instantly.
- Computer vision: It uses pattern recognition and deep learning to remember what is in an image or video. When machining can be processed, analyze and understand images, it will capture images or videos in real-time and interpret the surroundings.
- Natural Language Processing (NLP): Computers can analyze, understand and create human language, including words or speech. The next NLP stage is natural language interactions, which allow humans to communicate with computers using language to perform tasks [16],[37].

Besides, many technologies help and promote the efficiency of AI:

- Graphic Processing Unit (GPU): It is the key for AI since it increases the computing power required to repeat the processing process.
- Internet of Things: It generates a huge amount of data from the linked device which most of the information is not analyzed. The automated model using AI will allow us to make the most advantage of them.
- High-level algorithm: It is being developed and integrated as a new way to perform faster and multi-level data analysis. This intelligent process is the key to identifying and predicting rare events. It will understand complex systems and adjust them to get the most suitable situations.
- Application Programming Interface (APIs): It is a portable package of command codes that add artificial intelligence functionality into existing products. It can enhance your visual recognition ability to create a security system and answer questions that can explain information, create captives and subjects, or find interesting data formats and content [16],[37].

The type of AI can be divided into 3 sub fields: artificial intelligence, machine learning, and deep learning.

Artificial intelligence's brain is machine learning, which is learning from the things that we give to stimulate them, called input data. The machine will remember and send the result to display as a number or code. Besides, artificial intelligence can show by itself.

Machine learning requires a mechanism, which is the programming, called an algorithm designed by the data scientist. One of the most popular algorithms in deep learning is easy to use and can be used in many applications. However, in real work, a data scientist needs to design variables in deep learning itself and find other algorithms as a comparison to look for the most suitable algorithm in real work [44].

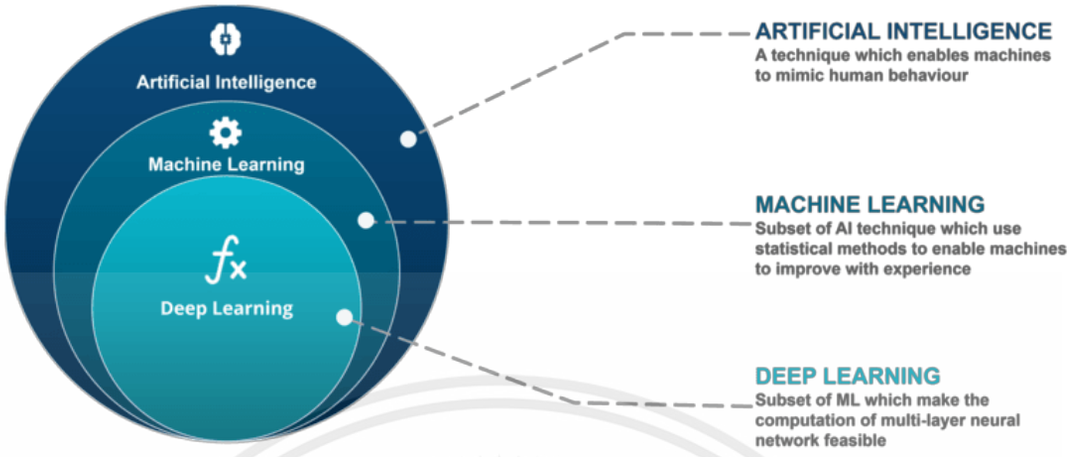

Figure 2.28 Relationship between AI, machine learning, and deep learning [19].

2.8.1 Machine learning

Machine learning uses algorithms to classify and analyze the data and learn from the data to create the model for decision making or prediction. It uses the dataset for training machine learning instead of writing code for working step by step. The dataset must be large enough to be learned to perform or execute tasks.

The way that machines learn is like a human, which is to learn from experience. The more we know, the easiest to predict what will happen next. When we face an event that we had never seen before, there is a lower probability of success than the possibility experienced before. The machine can be trained in the same way to increase the accuracy of prediction. The machine can see the example that we want them to see when we give the machine a similar example and find the result until the result appears. However, like humans, if a machine is ordered to search for something that has never been trained before, it is still challenging to find it [45].

2.8.1.1 Purpose of machine learning

1. Learning phase

The machine learns through the discovery of patterns or repeatedly patterns over and over again. Discovery must consider data, and in another important aspect is data scientist has to choose carefully what data can support and be suitable for problems. The properties used to solve problems are called feature vectors, a subset of all the solution's data.

Sometimes machines use weird algorithms to make it easier to implement and modify things. So, the learning stage is used to describe the data and collect it into a model [45].

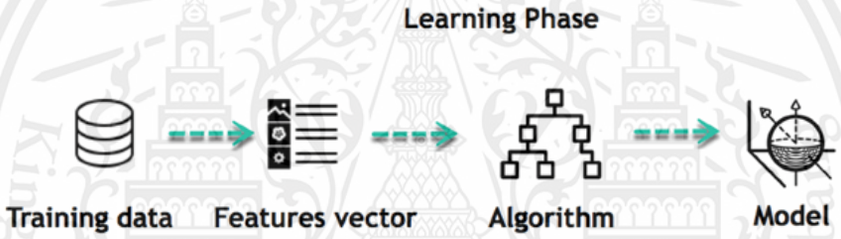

Figure 2.29 Learning phase [45].

2. Inference phase

When a model is created, the performance will be tested against information that it has never seen before. Those unusual data are converted into feature vectors, collected into models, and then give the prediction. The inference phase is a significant part of machine learning. There is no need to add any rules or train anything to a model, and you can use the previous model train to continue inference new data [45].

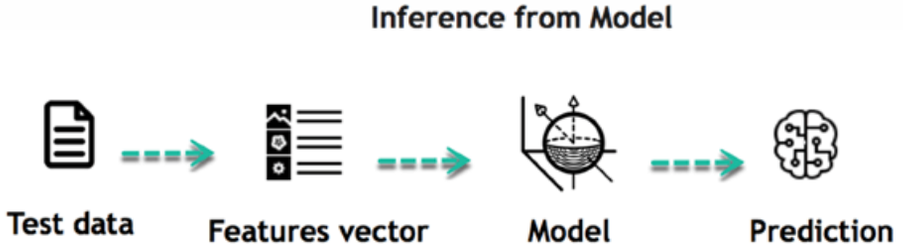

Figure 2.30 Inference phase [45].

2.8.1.2 Types of learning

Machine learning can be classified into two main types, which are Supervised Learning and Unsupervised Learning.

1. Supervised Learning

The supervised learning algorithm needs to uses data from humans, called training data, for the training part and feedback part to learn the relationship between the input and the output.

2. Unsupervised Learning

The algorithm examines only the entered data without producing any results, such as exploring the demographic data to determine that pattern. It can use when you don't want to know how the machines classify. But you need that algorithm to figure out the pattern and categorize it for you [45].

2.8.1.3 Challenge and limitation of machine learning

The first challenge with machine learning is the lack of data, or the lack of diversity in each data set, where machines can't learn without readily available data. Moreover, the lack of diversity of datasets makes it machines challenging to predict something. Machines require different data sets to deepen their learning. But it is difficult for algorithms to extract data when there is little difference in the data. Therefore, it has been suggested to have at least 20 trials per group to help machines learn. In conclusion, this limitation will lead to worsening estimation and prediction [45].

2.8.2 Deep learning

Deep learning is computer software that mimics the function of neurons in the human brain. It is a subset of machine learning. Algorithms of deep learning, created by combining multiple neural networks with the first layer responsible for receiving the data, are called input layers. The last layer responsible for transmitting the results is called the output layer. The layer between the first and the previous layer is called the hidden layer, as shown in Figure 2.24. The term deep learning is derived from multiple neural network layers connected. More than two hidden layers are considered deep

learning. Since these layers are structured to be stored in a stack, it is comparable to many layers, which will create a deeper structure [43].

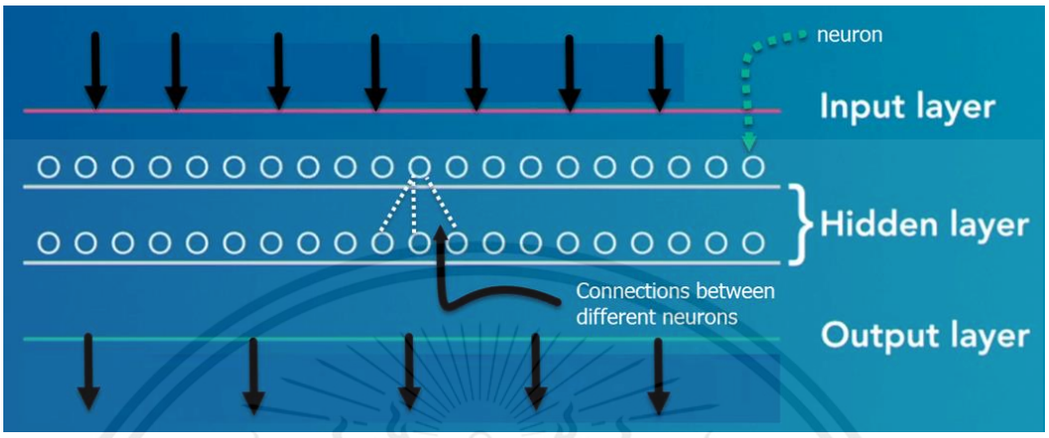

Figure 2.31 Deep learning structure [43].

Each hidden layer consists of many neural cells responsible for processing, receiving information from the upper layer, and sending the processed data to the lower layer. The advantage of this type of data transmission is that each layer can have independent weight, bias, and activation functions. The more data we input into a model, the more each layer will create complex features [43].

2.8.2.1 Workflow of deep learning

In solving many object detection problems to speech recognition, models that use deep learning can provide high accuracy results. Even we don't give any basic knowledge about those problems. We are just simply giving input data. It can automatically learn from data and synthesize knowledge by itself. For example, using deep learning in the gaming industry, we don't have to tell how to play. But let it learn from a large number of great players. It knows how to play the game automatically [43].

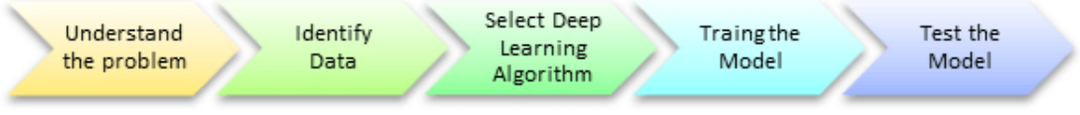

Figure 2.32 Workflow of deep learning [43].

Learning comes from 2 phases. The first phase is a nonlinear transformation to the input data and obtains the output data as a statistical model. The second phase is the mathematically derived model, which is done by derivative or the differentiate itself. These phrases are repeated repeatedly until a model is possible to achieve a satisfactory level of accuracy.

2.8.2.2 Classification of neural networks

1. Shallow neural network: Having only one hidden layer, one input layer, and one output layer.

2. Deep neural network: Having hidden layers of more than one layer. For example, the LeNet model by Google uses image recognition with 22 hidden layers [43].

2.8.2.3 Types of deep learning networks

1. Feed-forward neural networks

Feed-forward neural networks are the most straightforward structure models since their operations are carried in one direction. It receives data from the input layer and sends data to any hidden layer until it reaches the output layer [43].

Figure 2.33 Feed-forward neural network diagram.

2. Recurrent neural networks: RNN

Recurrent neural networks (RNN) are multi-layer neural networks that store information on a node, allowing it to receive data sequences and give output sequences. For simply explanation, RNN is multiple neural networks that connect and can be looped together. Therefore, RNN is very suitable for processing sequential data [12].

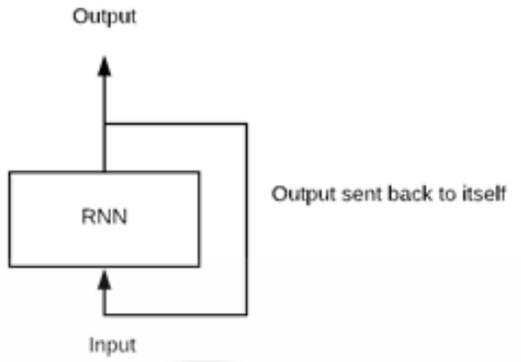

Figure 2.34 Recurrent neural network diagram [12].

Example of using RNN:

- Help securities traders to generate analytic reports.
- Detect abnormalities in the contract of financial statement.
- Detect fraudulent credit card transactions.
- Provide a caption for images.
- Power chatbots.
- Time-series data or sequences [12].

3. Convolutional neural networks: CNN

Convolutional neural networks (CNN) are multi-layered neural networks with a unique structure. It was designed to increase the ability to create more complex features based on data. CNN is highly responsive to perceptual tasks [43].

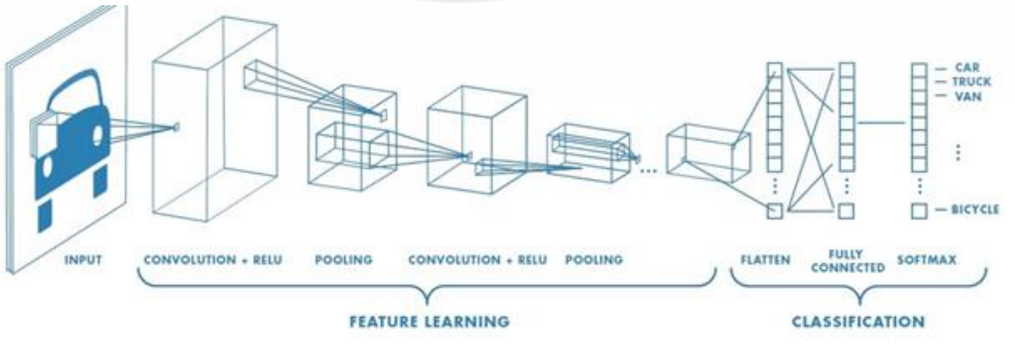

Figure 2.35 Convolutional neural network diagram [43].

CNN is often used to create features based on unstructured data, such as images. Example of using CNN:

- Suppose a CNN receives an input image as a picture. These images are stored in pixel format, typically one layer to store data in a greyscale format, and use the other three layers to store data in different colors.
- While the model learns at the hidden layer, the model finds a specific feature to the input it receives. For example, it might be a feature that checks the tail of a cat in this case.
- When the model completes the learning, it will answer each image as a probability. If the image has the highest likelihood of any kind, the model will respond that way [43].

2.8.2.4 Limitation of deep learning

1. Data labeling

Nowadays, most AI relies on training using supervise learning principles. Humans must manually name and classify the data (data labeling) before going to train. It must have a lot of information for training; thus, mistakes may occur. For example, self-driving cars company employ hundreds of people to label videos that will be used to train the system. Errors can occur from a large number of humans.

2. Obtain a huge training data set

Deep learning requires a large amount of data in training data to obtain a useful classification model. For example, 1000 data samples are needed to model. In some cases, more than 1 million samples are required for models to work with near-human efficiency.

3. Difficult to explain the problem

It is not easy for a human to explain a complex AI model. For example, the question of why a model decides that? It is another reason why AI is so slow to be accepted because some are difficult to explain [43].

2.9 Object detection

Object Detection is a computer technology based on Computer Vision and Image Processing principles used in AI work to detect specific objects such as humans, cars, buildings in images or videos [23].

In principle, before developing an object detection technology, it has to go through the Object Classification. Before the object classification is the image classification, what is that image, but object detection technology will indicate that What objects are there in the picture? This point will rely on the functionality of AI to help analyze the data as well. For example, the classification of objects can determine whether the object in the image is a cat, while object detection technology can identify the object. In the picture, there are cats and dogs [23].

Object Detection can penetrate many areas, such as Face Detection, Human Face Detection, Pedestrian Detection, which can be used in various applications, such as in security applications and driverless cars, etc. [52].

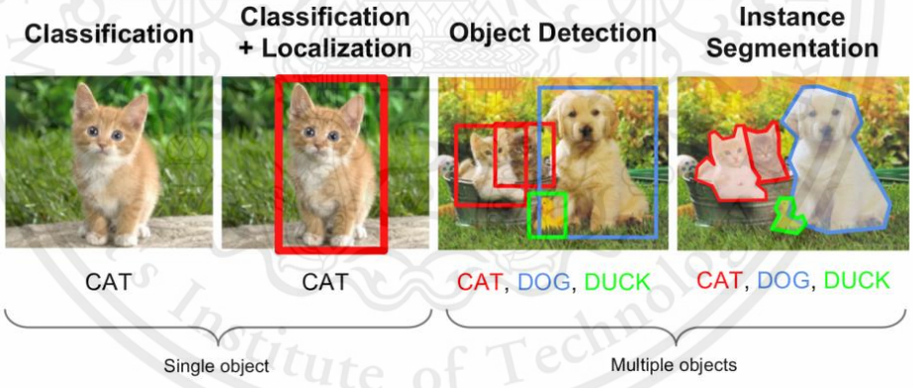

Figure 2.36 The object detection [52].

Object Detection is an AI object detection in computer vision that will recognize and detect objects in the form of area mark point detection. Popular area marking is drawing a box around an object (Bounding Box) or filling in color to every pixel of that object (called Segmentation) [52].

Figure 2.37 The object detection with AI [52].

2.10 Python language

The Python programming language is a high-level of the computer programming language. It is designed as an easy-to-read scripting language by eliminating the complexity of the language's structure and grammar. In converting the instruction set to the machine language, Python has an interpreter function, a line-by-line translation. The purpose is to enter a command into the processor for the computer to function as we want. Python programming language can also be used for many different types of programming without being limited to a specific job in any way (General-purpose language). Thus, it is widely used in many large global organizations such as Google, YouTube, Instagram, Dropbox, and National Aeronautics and Space Administration (NASA) [42].

Python is the most popular language for Machine Learning, Deep Learning, and Data Science right now because it’s easy to understand, has lots of libraries to use, and a large community [51].

2.11 Python libraries

Python is the one of the most popular languages of programming. It has a simple syntax and many libraries to use, allowing developers to build applications that write shorter code and make them more efficient. As a result, many developers have started building new libraries for Machine Learning [1].

2.11.1 Keras

Keras is one of the most suitable Python libraries for machine learning. It simplifies neural networks and provides the best utilities for model compiling, data set processing, graph visualization, etc. Keras uses Theano or TensorFlow as a backend and also offers useful portable models [51]. The best thing about this library is that it supports almost all Neural Network models and is fully compatible, convolutional, pooling, recurrent, embedding, etc. Nowadays, Keras is currently used by Netflix, Uber, Yelp, Instacart, Zocdoc, Square, and many more [1],[26].

2.11.2 Numpy

Numpy is another hugely popular Python Library for machine learning. It's both easy to use and can interact and learn very well. It makes complex mathematical applications to be more lot easier. Besides, Numpy can be used to display images, sound waves, and other binary raw streams as a real number array in N-Dimension. Numpy also simplifies coding and helps to understand the concept of popular libraries like TensorFlow. Numpy is used for many operations in Tensors, and the Array Interface is the most outstanding feature of Numpy [1],[26].

2.11.3 TensorFlow

TensorFlow is an open-source Python library developed by the collaboration of Google TensorFlow's Brain Team. A team aimed explicitly at developing machine learning and deep learning. TensorFlow is used to write many new algorithms related to Tensor operations. Since the neural network can be expressed as computational graphs easily, they can be used as a series of operations on Tensors using TensorFlow. Moreover, these Tensors are N-Dimensional matrices that will be used to describe or represent your information [1],[26].

2.11.4 Scikit-Learn

Scikit is another very useful Python library for working with complex data. It can work with NumPy and Scipy. Python Library has undergone several modifications. One of the major modifications is Cross-Validation Feature, which is now adding more than one metric capability. Other Training Methods like Logistics Regression and Nearest Neighbors have been improved [26]. Scikit-Learn can provides many

algorithms for standard machine learning implementations and data mining tasks such as reducing dimensionality, classification, regression, clustering, etc. [1],[51].

2.11.5 PyTorch

PyTorch is one of the most well-known machine learning libraries in terms of having many features. It is based on Torch, an Open-Source Machine Library written by Lua. PyTorch allows developers to create Dynamic Computational Graphs, and gradients can be calculated automatically. There is also an API for solving application problems related to Neural Networks. It facilitates Distributed Training by optimizing research and production. PyTorch is mainly used for NLP, which is the crucial TensorFlow [1],[26].

2.12 YOLO: You Only Look Once

The YOLO model ("You Only Look Once"; Redmon et al., 2016) is the primary attempt at a fast real-time object detector. Because YOLO doesn't undergo the region proposal step, it only predicts a limited number of bounding boxes. So it can make inferences in no time.

2.12.1 What is YOLO?

Object detection is the one of classical problems in computer vision. It works to acknowledge what objects are inside an image and where they are within the image. Object detection is more complex than classification because classification can recognize objects but does not indicate where the item is found within the image. It is unable to work on images containing over one object [36],[47].

YOLO might be a resourceful CNN for doing object detection in real-time. It is popular because it achieves high accuracy while also having the power to run in real-time [36]. The algorithm applies one neural network to the total image, and divides the image into predicts and regions bounding boxes and probabilities for each area. The anticipated probabilities weigh these bounding boxes. YOLO will train full images and optimizes detection performance directly. This model has several benefits over other object detection methods: YOLO may well be a high-speed detector. YOLO can see the entire image during training and test time, so it implicitly encodes contextual information about classes and their appearance. YOLO learns the object generalizable

representations, so that when trained on natural images and tested on the artwork, the algorithm outperforms other methods of top detection [47].

2.12.2 YOLO Algorithm

There are some different algorithms for object detection, and that they are split into two groups:

1. Algorithms supported classification that is implemented in two stages. First, they select regions of interest in a picture. Second, they used CNN to classify these regions. This solution is often slow because we've got to run predictions for each selected area. A widely known example of this algorithm is that the Region-based convolutional neural network (RCNN) and its cousins Fast-RCNN, Faster-RCNN, and the family's latest addition: Mask-RCNN. Another example is RetinaNet.

2. Algorithms supported regression – rather than selecting interesting parts of a picture, they predict classes and bounding boxes for the whole image in one run of the algorithm. The two best-known examples from this group are the YOLO family algorithms and Single Shot Multibox Detector (SSD). They're commonly used for real-time object detection as, in general, they trade a small amount of accuracy for big speed improvements [36].

The YOLO algorithm is important to determine what is being predicted. Finally, we aim to predict an object's category and the bounding box specifying object location. Each bounding box will be described using four descriptors:

1. center of a bounding box (bxby)

2. width (bw)

3. height (bh)

4. value cis corresponding to a class of an object (such as car, traffic lights, etc.).

Besides, we've got to predict the p_c value, which is the probability of an object within the bounding box.

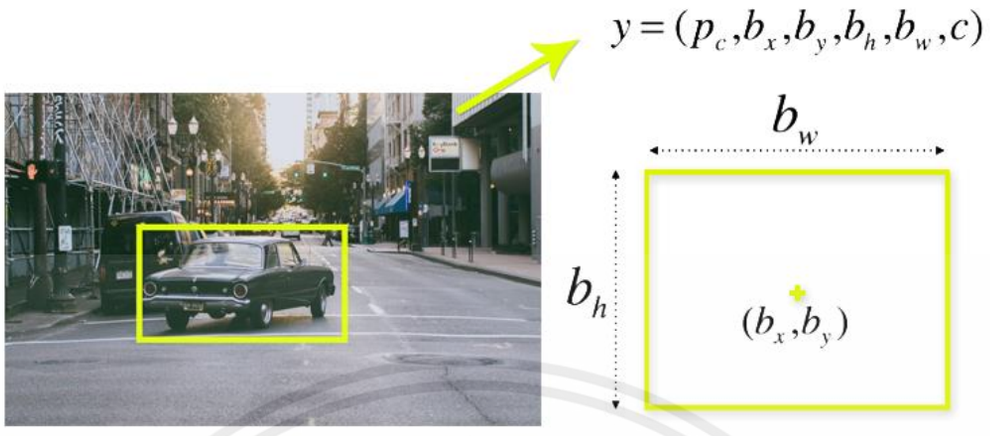

Figure 2.38 The YOLO algorithm with the bounding box [36].

As we mentioned above, when working with the YOLO algorithm, we aren't looking for interesting regions in our image that would potentially contain an object. Instead, we are splitting our image into cells, typically employing a 19×19 grid. Each cell is accountable for predicting five bounding boxes (if there's quite one object during this cell). Therefore, we attain a large number of 1805 bounding boxes for one image [36].

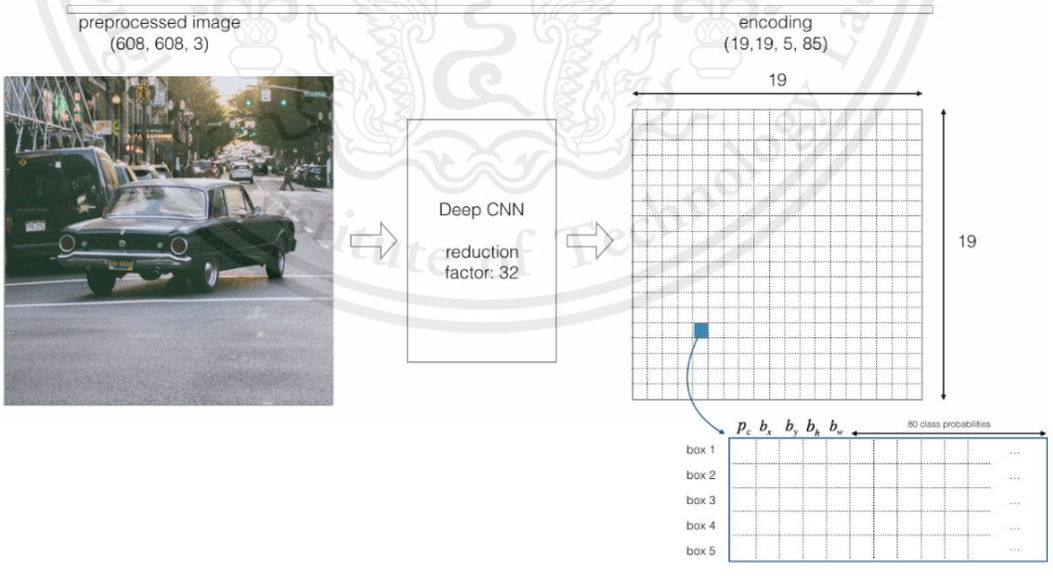

Figure 2.39 The algorithm of the bounding box [36].

Most of those cells and bounding boxes won't contain an object. Therefore, we predict the worth p_c, which removes boxes with low object probability and bounding boxes with the very best shared region during a non-max suppression process [36].

Figure 2.40 The non-max suppression process [36].

2.12.3 History

2.12.3.1 YOLO v1

YOLO v1 was introduced with a research paper called “You Only Look Once: Unified, Real-Time Object Detection.” in 2016 by Joseph Redmon et al., it was absolutely the initial paper by Redmon revolutionized the industry and adjusted the Real-Time Object detection methods. Just gazing at the image can detect the objects with a speed of 45 fps (frames per second). Another Fast YOLOv1 was ready to achieve 155 fps with little less accuracy.

1. Architecture

It trained the Darknet framework on the ImageNet-1000 dataset. But YOLOv1 has many limitations, prefer it can’t detect the objects properly when the objects are small. And it also can’t generalize the objects if the image is of various dimensions [39].

2.12.3.2 YOLOv2 (YOLO9000)

YOLOv2 was released by Ali Farhadi and Joseph Redmon in 2017. They collaborated for accuracy increment and major bug fixes. The published research was "YOLO9000 that is stronger, faster, better." the competitor of YOLO9000 was Faster R-CNN. This object detection algorithm uses Region Proposal Network & SSD to spot multiple objects from a picture.

Some of the features of YOLOv2 are:

- YOLOv2 added Batch Normalization to improve the input layer of the image by altering the activation functions.
- Anchor boxes.
- Higher-resolution input: the size of input has been increased from 224*224 to 448*448.
- Darknet 19 architecture with 5 Max Pooling layers and 19 convolution layers.
- Multi-Scale training [39].

2.12.3.3 YOLOv3

On March 25, another version of YOLO and a research paper called "YOLOv3: An Incremental improvement." are come up by Ali Farhadi and Joseph Redmon. YOLOv3 runs with 22 ms at 28.2 mAP with great accuracy at 320×320. It's three times faster than the previous SSD and four times faster than RetinaNet.

During this approach, Redmond uses the architecture of Darknet 53. It is a significantly improved version, and It had 53 convolution layers. YOLOv3 followed the methodology of the YOLOv2 version: YOLO9000.

Some of the improved features in YOLOv3 was:

- Feature Pyramid Networks (FPN)
- Darknet 53 architecture
- Class Predictions [39]

2.12.3.4 YOLOv4

It was released by Alexey Bochoknovskiy, Chien-Yao Wang, and Hong-Yuan Mark Liao that is a new team of three developers released YOLOv4 because Redmond

was not currently working for a long time. Alexey developed the Windows version of YOLO back in the days. YOLOv4 runs twice faster than EfficientDet with a comparable performance which was officially published on the YOLOv4 research paper.

Some of the new features of YOLOv4 is:

- YOLOv4 includes Pan aggregation network (PAN) and Cross-iteration batch normalization (CBN) methods.
- DropBlock regularization.
- Cross-Stage-Partial connections (CSP) that is a new backbone to enhance CNN.
- Self-adversarial-training (SAT) is A new data augmentation technique
- Weighted-Residual-Connections (WRC).
- Anyone that has a 1080 Ti or 2080 Ti GPU can run the YOLOv4 model easily [39].

2.12.3.5 YOLOv5

On 27 May 2020, YOLOv5 got released by Glenn Jocher (Founder & Chief Executive Officer (CEO) of Utralytics). Glenn introduced the YOLOv5 that is written in the Pytorch framework [39]. It is a state of the newest version of the series in YOLO object detection. With the 58 open-source contributors and continuous effort, YOLOv5 set the benchmark for models of object detection very high. It's already beats the EfficientDet and other previous YOLOv5 versions.

1. Model description

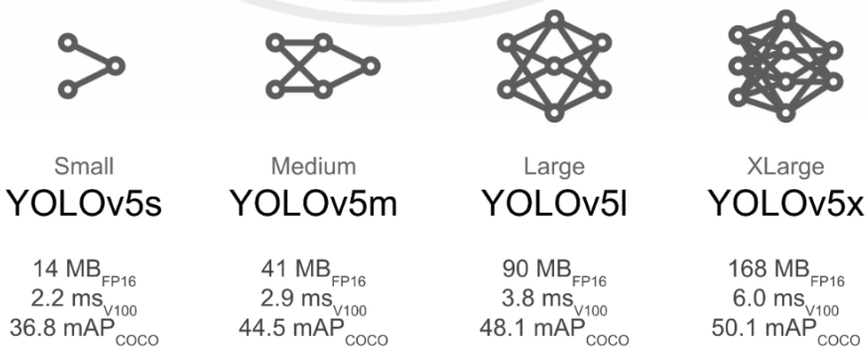

Figure 2.41 The model description of YOLOv5 [56].

YOLOv5 is compound-scaled object detection models family trained on the COCO dataset. It includes simple functionality for Test Time Augmentation (TTA), export ONNX, CoreML, and TFLite., and model ensembling, hyperparameter evolution [56].

Table 2.1 The comparison of each model in YOLOv5 [56]

Model	size	AP^{val}	AP^{test}	AP_{50}	$Speed_{V100}$	FPS_{V100}	params	GFLOPS
YOLOv5s	640	36.8	36.8	55.6	2.2ms	455	7.3M	17.0
YOLOv5m	640	44.5	44.5	63.1	2.9ms	345	21.4M	51.3
YOLOv5l	640	48.1	48.1	66.4	3.8ms	264	47.0M	115.4
YOLOv5x	640	50.1	50.1	68.7	6.0ms	167	87.7M	218.8
YOLOv5x + TTA	832	51.9	51.9	69.6	24.9ms	40	87.7M	1005.3

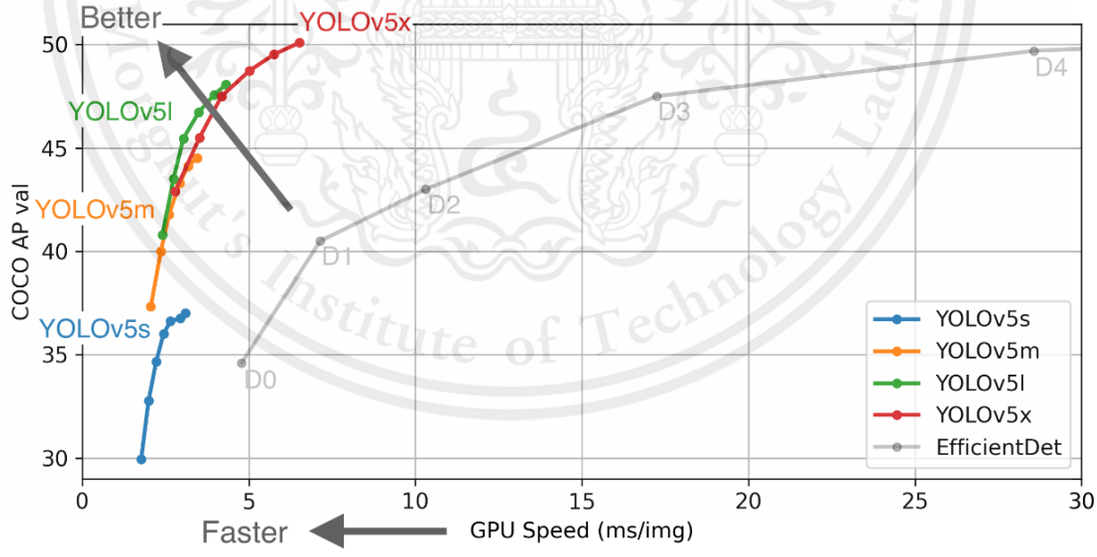

Figure 2.42 The comparison between each model of YOLOv5 [34].

2.13 Confusion Matrix

Before using the model, it is necessary to measure the performance of a model to confirm that the model is effective enough to be developed or used in various fields which most of the performance measurements will be measured from the available data table (Confusion Matrix).

The Confusion Matrix is an essential table for measuring machine learning's ability to solve problems of classification. And it is a necessary tool in evaluating the results of prediction or prediction based on the model that we created in machine learning by using the idea from comparing the proportion between what the model predicts and what reality happened [25].

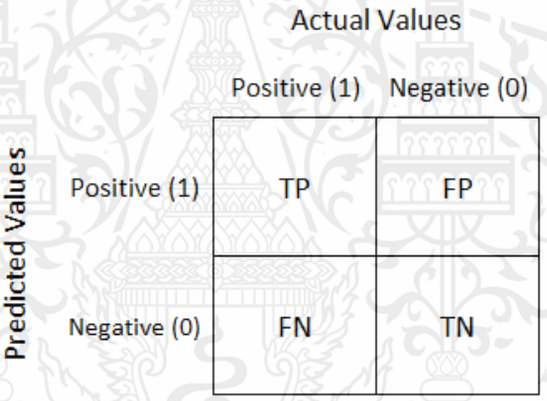

Figure 2.43 The example of a 2x2 Confusion Matrix table [25].

- True Positive (TP) is the number of correct predictions in which an example is positive. It is a positive class correctly identified as positive.
- True Negative (TN) is the number of correct predictions in which an example is negative. It is the negative class correctly identified as negative.
- False Positive (FP) is the number of incorrect predictions in which an example is positive. It is the negative class incorrectly identified as positive.
- False Negative (FN) is the number of incorrect predictions in which an example is negative. It is a positive class incorrectly identified as negative [25],[31].

In general, there are four commonly used in research and other works, and the equations are:

1. Sensitivity is the measure of positive examples labeled as positive by a classifier. It is also referred to as True Positive Rate or Recall. It should be higher.

$$\frac{TP}{TP + FN}$$

Sensitivity equation.

2. Specificity is the measure of negative examples labeled as negative by the classifier. It is also known as True Negative Rate. There should be high specificity.

$$\frac{TN}{TN + FP}$$

Specificity equation.

3. Precision is the ratio of the total number of correctly classified positive examples and the total number of predicted positive examples. It shows correctness achieved in positive prediction.

$$\frac{TP}{TP + FP}$$

Precision equation.

4. Accuracy is a measure of the validity of a model by considering all classes.

$$\frac{TP + TN}{TP + TN + FP + FN}$$

Accuracy equation.

5. F1-Score is the harmonic mean between precision and recall. F1 is created as a single metric that measures a model's ability (No need to choose between precision and recall because the average has been given) [31].

$$F1 = 2 * \left(\frac{precision * recall}{precision + recall}\right)$$

F1-Score equation.

2.14 Receiver Operating Characteristic (ROC) curve

ROC curve stands for the Receiver operating characteristic curve. We often use ROC curves as one of the test performance indicators to tell how well a test can separate disease and non-disease groups. The advantage of the ROC curve and area under the curve (AUC) is that it can tell the optimal cut-off point, at which point of the test accuracy is the highest and most reliable. Therefore, we can use that point as a cut-off point to divide the disease and the non-disease with the most accuracy and the minor mistakes. Besides, we can create multiple ROC curves to compare different tests in the same situation as most suitable.

The ROC curve had its beginning but during World War II about the 1940s. After the attack on Pearl Harbor in the United States, the ROC curve was developed to measure whether the receiver operators would miss a trap that how much did you catch on the Japanese plane. It's like measuring the performance of a radar detecting plane. But nowadays, the ROC curve is widely used as a diagnostic test performance tester.

Building a ROC curve is based on sensitivity, specificity, false-positive rate, false-negative rate. The test we are interested in will be used to divide two groups of people whether they have the disease or not. Patients received multiple cut-offs, especially numerical or continuous measurements, such as blood glucose levels divided into diabetic or non-diabetic groups when the cut-off value was changed. The false-negative rate will continually change. In reality, people with or without diabetes are the same.

This cut-off value will cause an exchange or trade-off between sensitivity and specificity and change the diagnostic accuracy of a particular test. If we increase the test sensitivity, such as the Fasting Blood Sugar (FBS) level at diagnosis of diabetes is reduced from 126 to 120. There will be more people with diabetes. But may get more people with fake diabetes as well. This way, we increased the sensitivity but reduced specificity, similar to the events recently occurring with guideline hypertension with reduced diagnostic criteria from 140/90 to 130/80, which increased sensitivity but reduced specificity.

Simultaneously, if we increase the diabetes threshold from 126 to 130 like this, people with diabetes will decrease, but some people with diabetes will miss a diagnosis. We had to increase specificity but lower the sensitivity, so the best cut-off point is the one that has the highest sensitivity and the highest specificity [50].

The ROC curve will come into play because the ROC curve will show us how much sensitivity and specificity each cut-off value has to distinguish people from disease and disease. If the point has the highest sensitivity and specificity, we use that point as the cut-off.

ROC curve is plotted between the x and y-axis.

Where The x-axis is the false positive rate or 1-specificity.

The y-axis is true positive rate or sensitivity.

Creating a ROC curve starts with sorting the disease data diagnosed as being or not suffering from the gold standard/reference standard. Then, we take results of our test to contain the sorts of the test that we are interested in, which is usually as a number from highest to lowest, such as from highest to lowest FBS with a diagnosis from other standards as

After that, we calculate the sensitivity, specificity of each test value. How much would it be if using that value as a cut-off? For example, suppose we set FBS 560 as the cut-off value of a Diabetes mellitus (DM) diagnosis like this. In that case, specificity is equal to 100% in diabetes, but the sensitivity can be minimal, such as 1%, because it will cause enormous false-negative rates. There will be many people with sugar levels 126-559 who should be diagnosed with diabetes but miss out on the criteria of cut-off value at this level. On the other hand, if we set FBS 80 as the cut-off value of this type of diagnosis, the sensitivity would be very high, perhaps closer to 100%. But, the specificity would be much less, resulting in a large false positive.

Our task is to calculate each point. Then take the calculated value and plot it on the ROC curve. We will get a curve that looks a slight curvature towards the corner if the perfect test should have this angle as close as possible to the top left corner. Because the top left corner of the ROC curve is a point at sensitivity is equal to 100% and

specificity is equal to 100%. If any test sensitivity is equal to 100%, specificity is equal to 100%. It will pass the top corner.

The test group that does not mean anything (worthless test) is a classification between the disease and the non-disease. It can be divided by chance, or By chance is a line that runs through the middle. From the bottom left corner to the top right corner: every point on this line has a combination of sensitivity, specificity is equal to 100%, which is calculated as the likelihood ratio is equal to 1, which means no effect, no diagnostic value.

AUC calculations can be calculated using statistical programs, which will indicate the overall test accuracy of that particular value, divided by the following values:

0.9-1.0: very good, excellent

0.8-0.9: good

0.7-0.8: fair

0.6-0.7: poor

0.5-0.6: fail

< 0.5: Worthless test, better roll the dice

The closer the AUC is to one, the higher the test accuracy because it indicates the probability that the diagnostic kit will be accurate [50].

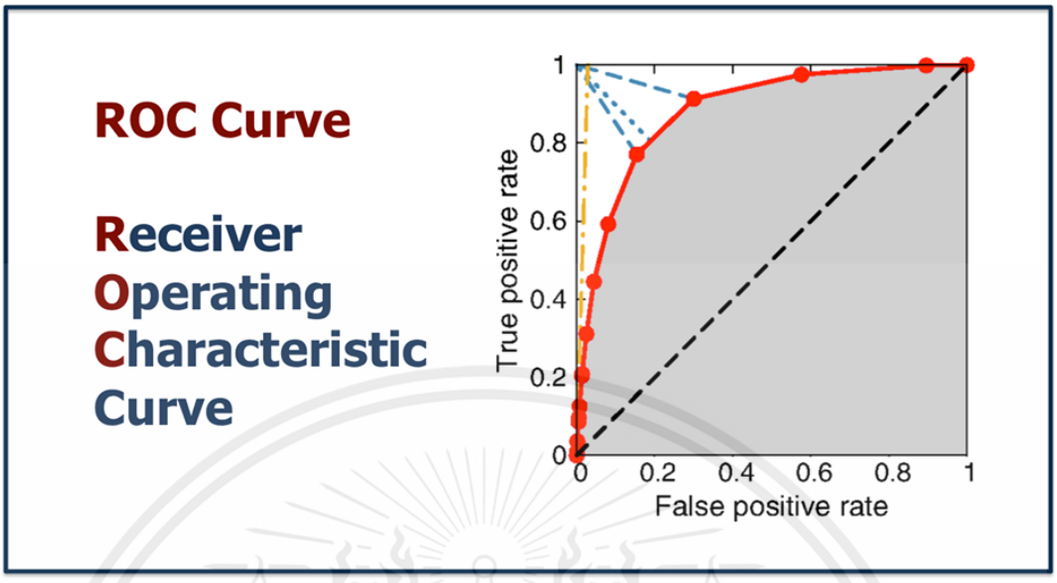

Figure 2.44 The ROC curve [50].

2.15 Graphic User Interface (GUI)

Graphical User Interface (GUI) is a symbolic interface to users. The computer program's design is designed to interact with the user by using icons, images, and other symbols to represent different aspects of the program instead of typing commands in work. It also allows users to work more efficiently and quickly without memorizing many program commands, which helps computer users communicate with the system through images—for example, using the mouse to select the icon instead of typing the command as before. Some programs have many commands, such as the Autocad drawing program, with many commands used to create images. The users can use the mouse to select the command they want to draw from Icons that appears in the program. It can be used without typing any commands on the keyboard, so it speeds up work and doesn't have to waste time learning and remembering the commands you want. It's just looking at the Icons that appear in the program. And it can be used immediately [46]. Examples of programs that help design a GUI-based program, such as Microsoft Visual Basic and python.

Creating a simple GUI that works across multiple platforms is complicated. But you'll be able to use Python and the PySimpleGUI package to form nice-looking user

interfaces that you just want. PySimpleGUI may be a new Python GUI library that has been gaining plenty of interest recently [27].

In 2018, PySimpleGUI was launched. So, it is a comparatively new package that compared with wxPython or PyQt.

PySimpleGUI has four ports:

1. Tkinter: The Tkinter package (“Tk interface”) is the Tk GUI toolkit that is the standard Python interface. Tkinter and Tk are available on most Unix platforms and Windows systems.

2. PyQt: PyQt may be a set of Python bindings for Qt application framework of the Qt Company and runs on all platforms supported by Qt, including iOS, Android, Windows, Linux, and macOS. PyQt4 supports Qt v4, PyQt5 supports Qt, and v5PyQt6 supports Qt v6. The bindings are implemented as a collection of Python modules and contain over 1,000 classes.

3. wxPython: wxPython is the GUI toolkit cross-platform for the Python language. It allows Python programmers to build programs with a sturdy, easily and simply, and highly functional graphical user interface. It was implemented as a group of Python extension modules that wrap the GUI like Python and wxWidget. wxPython is Open Source, which suggests that it is free for anyone to use. Therefore, the American Standard Code for Information Interchange (ASCII) text file is offered for anyone to appear at and modify. And anyone can enhancements or contribute fixes to the project. wxPython could be a cross-platform toolkit. It implies that the identical program will run on multiple platforms without modification. Nowadays, supported platforms are Microsoft Windows, Mac OS X and macOS, and Linux or other Unix-like systems with GTK2 or GTK3 libraries. In most cases, the native widgets are wont to provide a 100% native look and sympathize with the appliance. Since the programing language is Python, wxPython programs are simple, easy to put in writing, and simple to grasp.

4. Remi: Remi may be a GUI library for Python applications. It rendered in web browsers. It allows you to access your interface remotely and locally [27].

PySimpleGUI wraps portions of each of those other packages and makes them easier to use. However, each of the ports must be installed separately. PySimpleGUI covers the whole lot of Tkinter, which comes with Python. PySimpleGUI has covered most of PySide2, but only a tiny portion of wxPython. After installation of PySimpleGUI, you will get the Tkinter variant by default.

Depending on which variant of PySimpleGUI you utilize, applications that you create with PySimpleGUI might not look native to their platform. PySimpleGUI continues to be quite powerful and may get most things through with a touch of labor [27].

CHAPTER 3
METHODOLOGY

This chapter describes the design of the hardware part and how to do the software part. It is divided into four parts to understand easily. First is endoscope development that will describe why we select this device for the project. The second is hardware design and manufacture that describe the details of our endoscope. The third is the 3D visualization system development that explains how to make a 3D image from a 2D image.

3.1 Endoscope development

Previously, the colposcopy camera used has characteristics like a microscope, which is stationary and cannot control movement. Therefore, we have an idea that we should develop an endoscope in various fields to make it more convenient for users to diagnose patients. For example, tissue image resolution is higher, shorter time processing of diagnosis and device modification to be handheld and controlled.

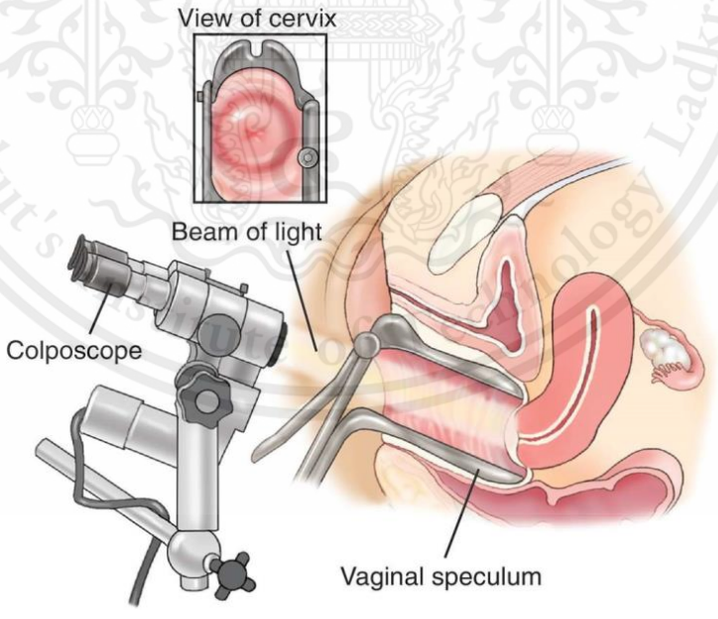

Figure 3.1 Camera use in old colposcopy [32].

3.1.1 Camera Selection

We plan to design the camera to have the smallest size and can receive a high-resolution image. Therefore, we choose the CMOS endoscope, which is small and highly effective in displaying the image with clarity. CMOS stands for Complementary Oxide Semiconductor, which is sensor behaves. Each pixel has a sub-circuit to instantly convert the value of incoming light into a digital signal without being sent out to convert with an external circuit.

Figure 3.2 CMOS endoscope [6].

3.1.2 Camera calibration

3.1.2.1 Distortion calibration

The camera may be capable of image distortion, which caused the image to be distorted from reality. Therefore, we calibrate the distortion of the camera and optimize them. The distortion calibration will use the MATLAB program, as shown in Figure 3.3. First, we print the checkerboard, which is used with camera calibration, as shown in Figure 3.4. Then, we capture the image of the checkerboard and put it into the MATLAB program. Besides, as we make a stereo camera, we have to use a stereo camera calculator in MATLAB to calibrate the distortion.

Figure 3.3 MATLAB program [9].

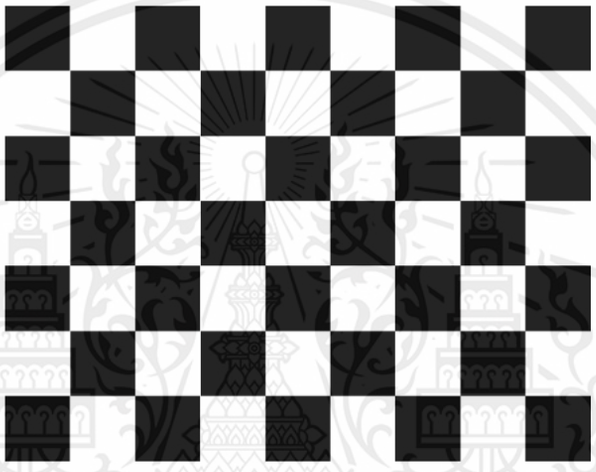

Figure 3.4 Checkerboard [35].

3.1.2.2 Alignment calibration

The 3D colposcope consists of 2 CMOS endoscopes align together in the same plane to produce a good 3D image. 2 CMOS endoscopes should have an appropriate alignment. Therefore, we calibrate the alignment of both endoscopes by using the MATLAB program. First, we capture the checkerboard image from many perspectives, as shown in Figure 3.5. Then, we put these images into the Stereo Camera Calibrator Application of MATLAB to calibrate the alignment of 2 CMOS endoscopes.

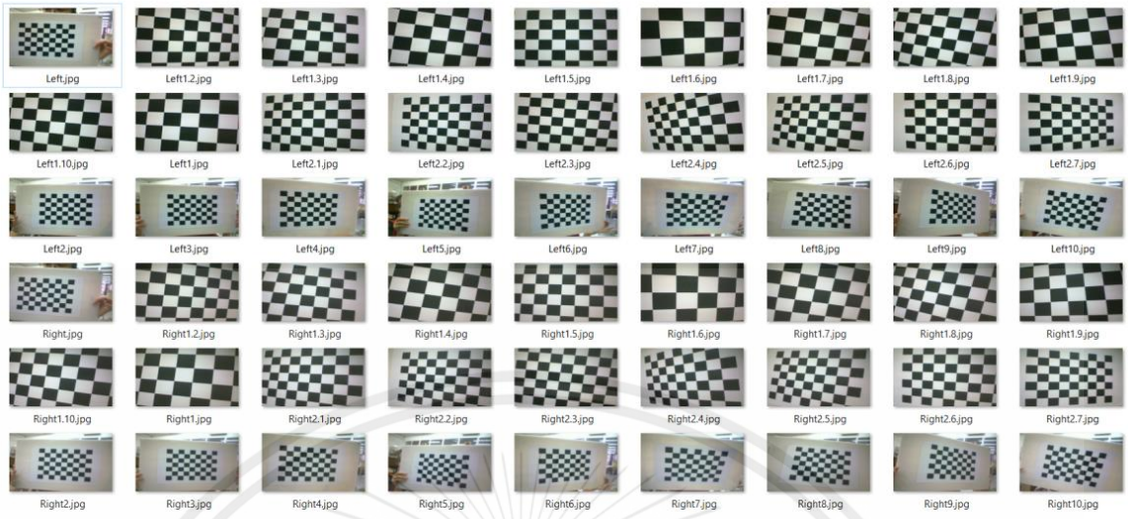

Figure 3.5 Image captured from left and right camera.

3.1.2.2 Illumination calibration

In illumination calibration of the camera, the power meter (PM100D - Compact Power and Energy Meter Console, Digital 4" LCD) is used to measure the light intensity of each endoscope, as shown in Figure 3.6. We turn on the maximum level of light from each endoscope to hit the detector plate of the power meter. It will measure the power of that light in uW unit. Each endoscope will be measure five times to find the average value. After that, the average value from the illumination measurement of both endoscopes will be compared.

Figure 3.6 Power meter [11].

3.2 Hardware design and manufacture

In designing the device, we concern about the physiological characteristic and size of the cervix and vagina. It is relatively straight by the vagina's nature and has a depth of around 10-15 cm. from the vulva. Therefore, we design the device to be a long straight tube according to the physiological characteristic of the vagina. The device has a handheld handle, for users will be able to use it conveniently.

This device consists of two parts, which are CMOS endoscope encapsulation and a handheld handle. The CMOS endoscope encapsulation part is a straight tube with two hollow tubes inside for insert two CMOS endoscopes to receive two images from a slightly different perspective. The handheld handle part is a long oval tube with an angle of about 20 degrees with the CMOS endoscope encapsulation part, allowing users to grip it correctly.

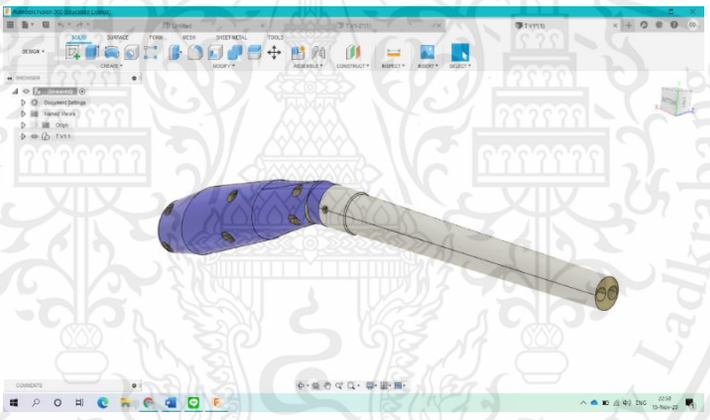

Figure 3.7 Overall of device designing.

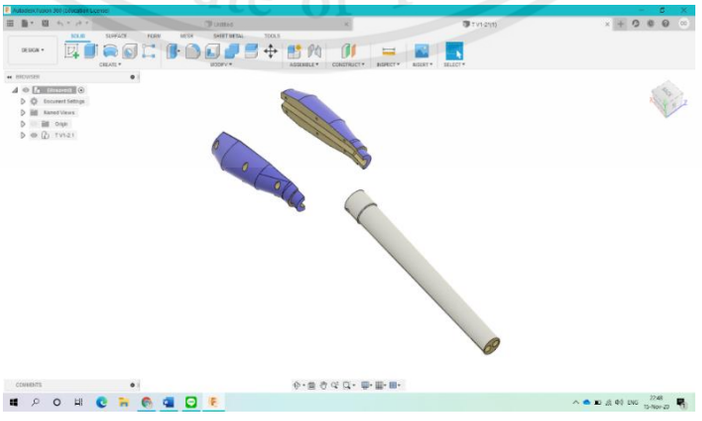

Figure 3.8 Separate part of device designing.

The program used to design the device is Autodesk Fusion 360. This program can easily design a device and visualize it as real to manufacture devices as many more details as we need it to be.

Figure 3.9 Autodesk Fusion 360 program [7].

In designing the device, we concern about the material that uses for manufacturing the medical devices. Therefore, we decide to use two types of medical materials, Stainless steel 316LVM (Low-carbon Vacuum Melted) and Acrylonitrile-Butadiene-Styrene (ABS) plastic.

Stainless steel 316LVM is called medical-grade stainless steel. It is passing the vacuum melt process to achieve the highest purity and cleanliness for surgical implantation. It is an excellent physiological environment resistance, resistance to general corrosion and intergranular corrosion, and resistance to pitting and crevice corrosion.

ABS plastic is one of the most widely accepted in the medical industry. It has properties of hardness and toughness, good impact and abrasion resistance, heat and chemical resistance. Mostly, ABS plastic is popularly used to make medical device trays and handles. Therefore, we designed a CMOS endoscope encapsulation part made of stainless steel 316LVM and a handheld handles part made of ABS plastic for convenience to users and safety for patients.

3.3 3D visualization system development

In making 3D images, we refer to the research 3D Surface Reconstruction from Endoscopic Videos:

Endoscopy is a popular procedure to help surgeons investigate a patient's organ of interior and find abnormal regions (e.g., polyps). However, it requires excellent expertise by using only a stream of 2D images of the physicians and the interior. It can miss some polyps. In this case, the interior surface's organ of a 3D reconstruction will be beneficial. It turns the 2D images into a 3D model. The physicians could spend more time scrutinizing the interior surface. The reconstruction result will also provide more details about the patient's organ, including a coordinate system, and could be saved for later uses [18].

From the research study, we have known that 3D visualization can increase the image's detail rather than the presentation of 2D images. Besides, it can help the doctor diagnose patients more efficiently and more accurately.

Furthermore, we refer to the research Development of 3D High Definition Endoscope System:

Recent advances in technology have paved the way for the 3D endoscope that has propelled minimum invasive surgical methods. Experienced surgeons can perform the conventional two-dimensional endoscopy-based Minimally Invasive Surgery (MIS). Besides, the inability to perceive depth was the leading cause of migration to the 3D endoscope. In this research, they present a prototype of the stereo endoscopic system. The stereo endoscope problem such as accessibility, severe lens distortion, and inhomogeneous illumination are removed in the proposed system. Besides, the stereo calibration and rectification have been executed for 3D visualization. The polarization

technique is used for depth perception. The proposed system also allows a real-time High Definition (HD) view to the surgeons [28].

We have known that surgery using 2D images can cause invasion or injury from surgery from the research study. Because they can distinguish the depth of tissues not enough, making surgery may be difficult, and there may be a higher risk of injury. Using 3D imaging can help the user or the surgeon see the tissue's depth and the distance between tissues or organs more clearly than the 2D image, allowing users to work more conveniently and efficiently.

Therefore, in making 3D images, we decide to use two CMOS endoscopes and writing Python code to get 3D images. We use Python because Python is one of the most popular languages of programming. It has a simple syntax and many libraries to use, allowing developers to build applications or adapt code for more efficiency.

3.3.1 Image receiving

We test 2 CMOS endoscopes using python code to acquire images to verify that both endoscopes could display and receive images according to their specifications. The code for receiving images is shown in figure 3.10.

```
import cv2

webcam1 = cv2.VideoCapture(1)
webcam2 = cv2.VideoCapture(2)
while True:
    try:
        check, frame1 = webcam1.read()
        check, frame2 = webcam2.read()
        cv2.imshow("Capturing", frame1)
        cv2.imshow("Capturing", frame2)

        if cv2.waitKey(1) & 0xFF == ord('q'):
        break

cap.release()
cv2.destroyAllWindows()
```

Figure 3.10 Python code for receiving images.

3.3.2 Image saving

After examining two endoscopes, we capture and save images to check the resolution of images to achieve the required resolution. The code for saving images is shown in figure 3.11.

```
import cv2

webcam1 = cv2.VideoCapture(1)
webcam2 = cv2.VideoCapture(2)
while True:
    try:
        check, frame1 = webcam1.read()
        check, frame2 = webcam2.read()
        cv2.imshow("Capturing", frame1)
        cv2.imshow("Capturing", frame2)

        key = cv2.waitKey(1)
        if key == ord('s'):
            img1_resized = cv2.resize(frame1,(1920,1080))
            cv2.imwrite(filename='saved_img1.jpg', img=img1_resized)
            img2_resized = cv2.resize(frame2,(1920,1080))
            cv2.imwrite(filename='saved_img2.jpg', img=img2_resized)

            cv2.waitKey(1650)
            cv2.destroyAllWindows()
            print("Processing image...")
            print("Image saved!")

        elif key == ord('q'):
            print("Turning off camera.")
            webcam1.release()
            webcam2.release()
            print("Camera off.")
            print("Program ended.")
            cv2.destroyAllWindows()
            break

    except(KeyboardInterrupt):
        print("Turning off camera.")
        webcam1.release()
        webcam2.release()
        print("Camera off.")
        print("Program ended.")
        cv2.destroyAllWindows()
        break
```

Figure 3.11 Python code for saving images.

3.3.3 3D image-making

After we got two images with slightly different perspectives from two CMOS endoscopes, we take those images to create a 3D image in a polarized system by combining two images. Combining images can be done by many methods, overlapping images and joining images. Another system is the anaglyph system, which will combine images by merging images.

3.3.3.1 Overlapping image method

This method overlaps two images from two CMOS endoscopes, which lining in the same plane but have a slightly different position. Therefore, we can make a 3D image with higher depth due to the different perspectives of images. The code for the overlapping image is shown in figure 3.12.

```
import cv2

webcam1 = cv2.VideoCapture(1)
webcam2 = cv2.VideoCapture(2)
while True:
    try:
        check, frame1 = webcam1.read()
        check, frame2 = webcam2.read()

        key = cv2.waitKey(1)
        polarizedadd = cv2.add(frame1,frame2)
        polarizedadd_resized = cv2.resize(polarizedadd,(1080,720))
        cv2.imshow("Polarized overlap ",polarizedadd_resized)

        if key == ord('q'):
        break

cap.release()
cv2.destroyAllWindows()
```

Figure 3.12 Python code for overlap images.

3.3.3.2 Joining the image method

In this method, we take two images received from two CMOS endoscopes to join horizontally together. Then display the image with a 3D monitor to convert the image into a 3D image. The resulting 3D image will have more depth due to the image with a different perspective. This method is another technique used in a 3D polarization system to produce clear and deep images. The code for the joining image is shown in figure 3.13.

```
import cv2

webcam1 = cv2.VideoCapture(1)
webcam2 = cv2.VideoCapture(2)
while True:
    try:
        check, frame1 = webcam1.read()
        check, frame2 = webcam2.read()
        cv2.imshow("Capturing", frame1)
        cv2.imshow("Capturing", frame2)

        key = cv2.waitKey(1)
        polarizedconcat = cv2.hconcat([frame1,frame2])
        concat_resized = cv2.resize( polarizedconcat,(1280,720))
        cv2.imshow("Polarized Concat",concat_resized)

        if key == ord('q'):
        break

cap.release()
cv2.destroyAllWindows()
```

Figure 3.13 Python code for join images.

3.4 Realtime object detection development

3.4.1 Deep learning development

We collect image data from the WHO's Colposcopy Atlas for deep learning, as shown in Figure 3.14. All images are divided into only two classes: normal and abnormal class as we consulted with the doctor. The reason is all available images are not sufficient to separate according to the severity of cervical cancer. Then, we label the image or specify the position in each image that where is normal or abnormal area. The program uses to label the image is labelImg, as shown in Figure 3.15.

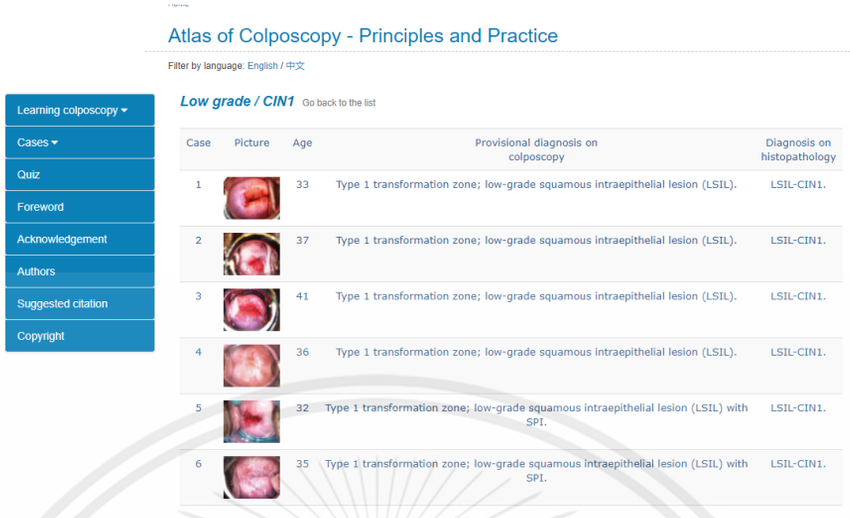

Figure 3.14 Colposcopy atlas from WHO.

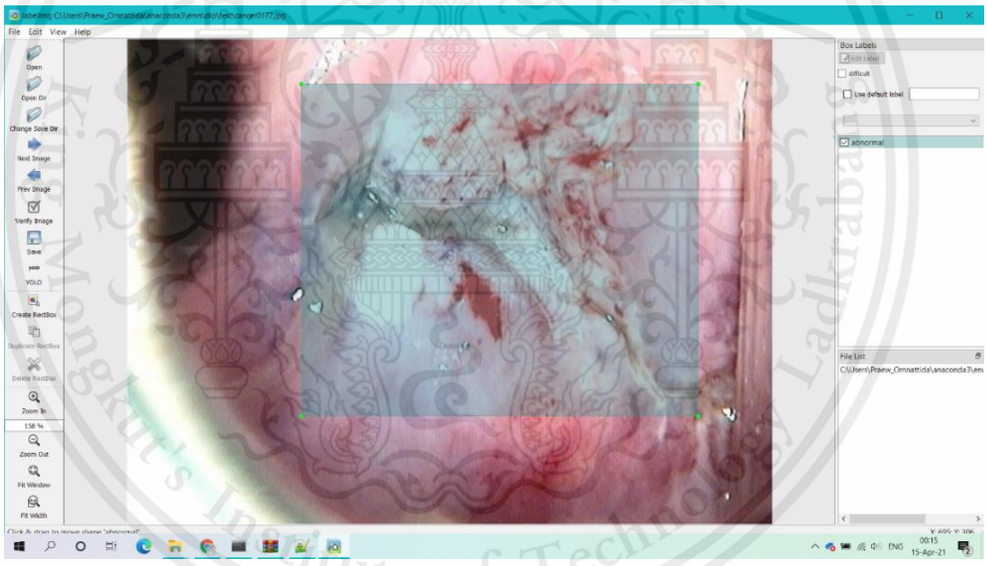

Figure 3.15 Labeling image by using labelImg program.

The images are divided into 95% for training the system and 5% for final testing of how well the model will work with the image they have never seen before. After that, the 95% of images will be divided again into three parts: train folder with 80% of image data which will be used to train the model, test folder with 10% of image data which will be used to test the model, and validation folder with 10% of image data which will be used to modify the model. The number of images shown in Table 3.1.

Table 3.1 Image data

Classes	Part 1 (95%)			Part 2 (5%)
	Train	Test	Validation	
Normal	392	50	50	13
Abnormal	338	42	42	11
Total	730	92	92	24

3.4.1.1 Model training

We have written code using python in model training and choose the YOLOV5 model to develop an automated image analysis system. This model can perform real-time object detection and provide good performance. Therefore, we chose this model to develop the system. We have done model training repeatedly to remodel and find the best models to use in the automated image analysis system. Model training is shown in Figure 3.16.

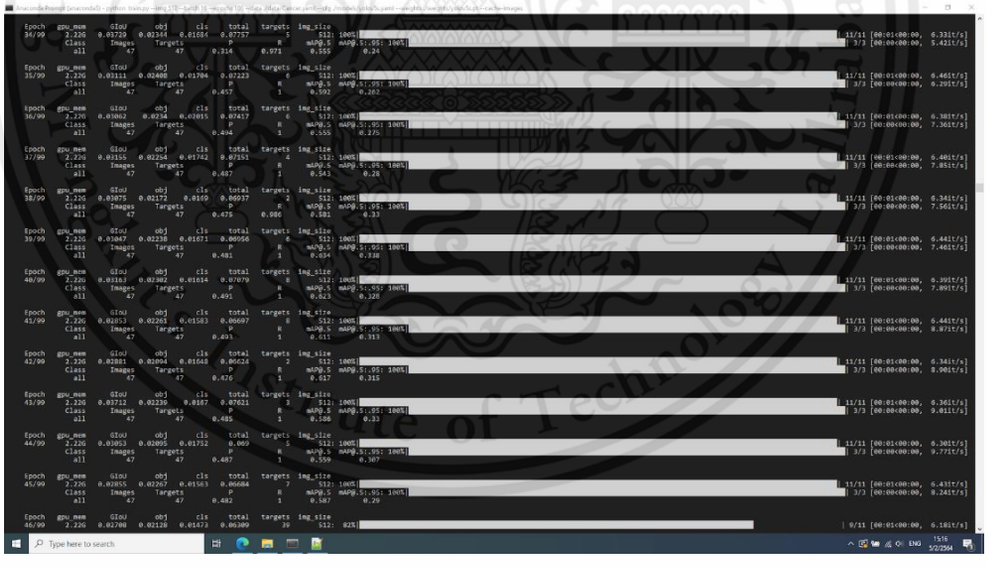

Figure 3.16 Model training.

3.4.1.2 Model Testing

In model testing, we test each model by using the file obtained after training to test with images from the test folder to see the performance of each model, including finding ways to adjust the model to be more efficient. Model testing is shown in Figure 3.16.

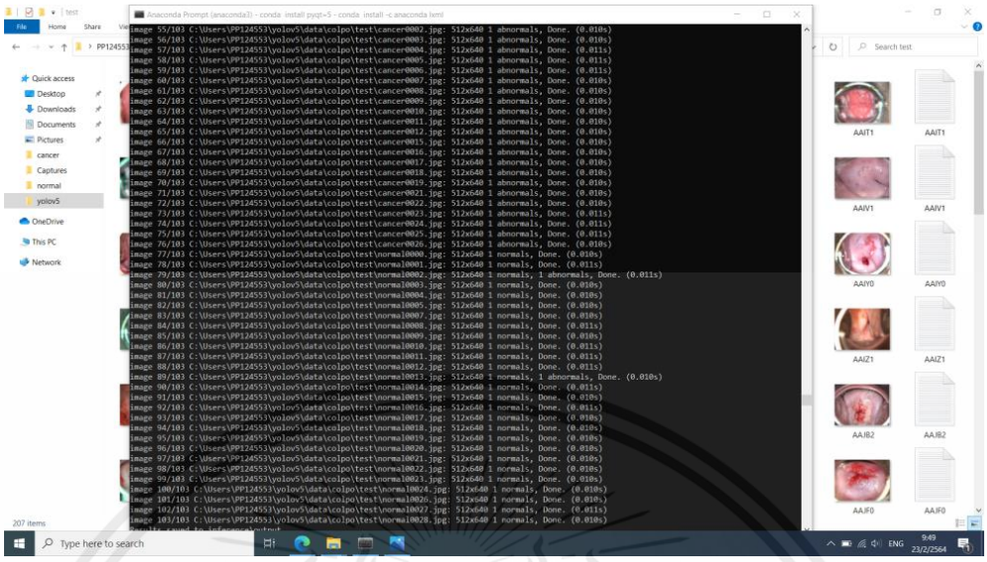

Figure 3.17 Model Testing.

3.4.2 Confusion matrix

After model testing, we took the prediction results of each model to find a confusion matrix, where a normal class is a negative prediction, and an abnormal class is a positive prediction. The values that need to be counted and recorded are TP, TN, FP, FN. Then, these values will be used to calculate the sensitivity, specificity, accuracy, and precision of each model according to the equation as follows:

- Sensitivity = $\frac{TP}{TP+FN}$
- Specificity = $\frac{TN}{TN+FP}$
- Accuracy = $\frac{TP+TN}{TP+TN+FP+FN}$
- Negative Predictive Value = $\frac{TN}{TN+FN}$
- Precision = $\frac{TP}{TP+FP}$

3.4.3 Realtime object detection

After calculating and getting the best model, we will select that model for doing real-time object detection. The command code used to run real-time object detection is different from conventional object detection. It uses a source of the image from the webcam or the CMOS endoscope inside the device instead of the image from the folder. The command code is shown in Figure 3.18.

```
$ python detect.py --source 0  # webcam
                           file.jpg  # image
                           file.mp4  # video
                           path/  # directory
                           path/*.jpg  # glob
                           rtsp://170.93.143.139/rtplive/470011e600ef003a004ee33696235daa  # rtsp stream
                           rtmp://192.168.1.105/live/test  # rtmp stream
                           http://112.50.243.8/PLTV/88888888/224/3221225900/1.m3u8  # http stream
```

Figure 3.18 Code for run model in each source.

3.5 Graphic User Interface development

GUI is written using Tkinter, a standard library of python that can provide a fast and easy way to create GUI applications. GUI consists of 2 pages, the first page for entering patient's information as shown in Figure 3.19 and the second page for selecting the desired mode as shown in Figure 3.20. The system consists of 4 modes:

- Normal mode for displaying original images from one camera.
- AI mode for real-time cervical cancer diagnosis.
- Polarized mode for displaying 3D polarized images must be used with a 3D monitor and 3D polarized glasses.
- Fluorescence mode for displaying images obtained by staining the cervix with a fluorescent agent (Indocyanine green (ICG)), which can help see the cancer cells on the surface of the cervix more clearly.

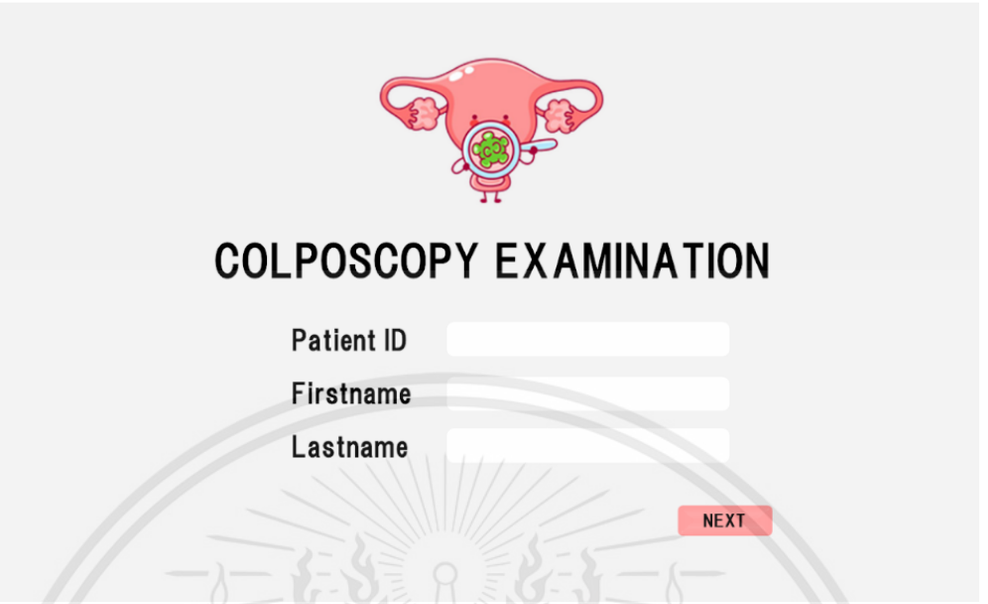

Figure 3.19 First page of GUI.

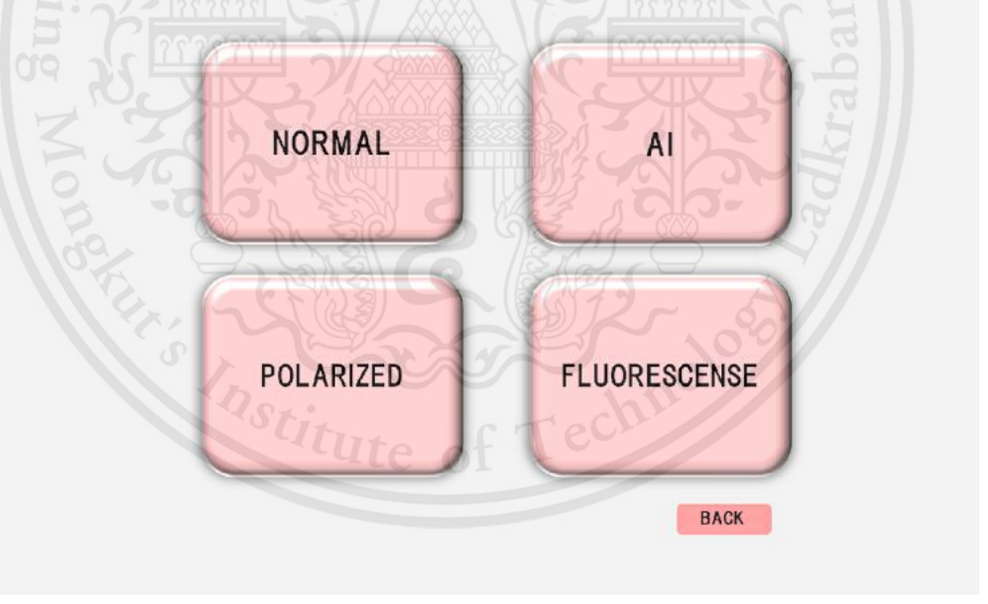

Figure 3.20 Second page of GUI.

3.6 System assembling

After developing the hardware part, which is the CMOS endoscope with handle, and software part, which is a system for helping to develop real-time cervical cancer, we have designed and ordered some additional components that can support and provide convenience to users.

3.6.1 Footswitch

The footswitch used in the system is Scythe USB Double Foot Switch II, as shown in Figure 3.21. We adapt footswitch into the system to help users to use the system more conveniently. The function that we provide is for users to capture images and exit without using their hands.

Figure 3.21 Scythe USB Double Foot Switch II.

We have installed a footswitch program named Usbhid Keyboard 2.40 to define each button as any letter key instead of a keyboard. The left button is defined as the letter S for saving an image, and the right button is defined as the letter Q for quit from the program, as shown in Figure 3.22.

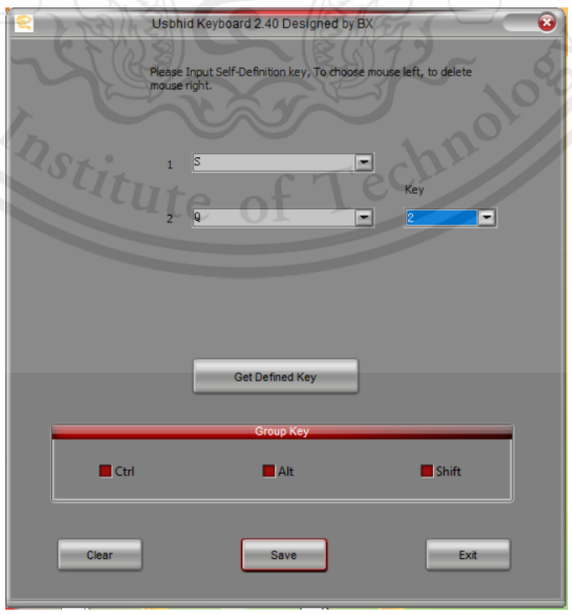

Figure 3.22 Footswitch setting.

3.6.2 Supporting components

Since we want the system to run through the laptop and keep the laptop to reduce the operating space, we design and customize the metal box to carry the laptop, as shown in Figure 3.23.

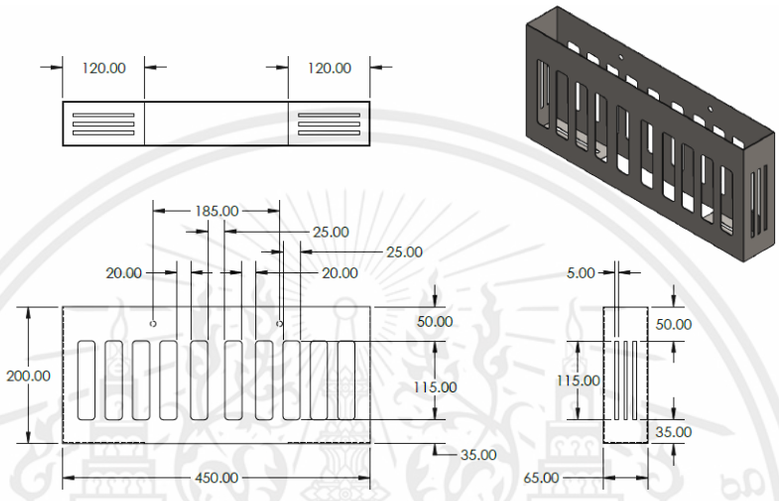

Figure 3.23 Metal box design.

Since running the system has to use electricity all the time. Therefore, we prevent power shortages by designing a shelf to place uninterruptible power supplies (UPS) which come to support the system, as shown in Figure 3.24.

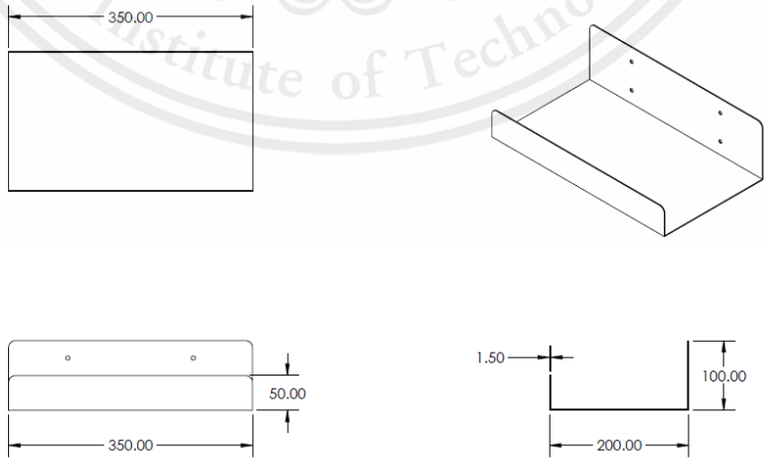

Figure 3.24 Shelf design.

Besides, we use articulated arms to help carry the keyboard and mouse instead of a laptop. Moreover, this articulated arm will carry a 3D colposcope that is the main device. And because this arm is flexible and easy to bend, doctors can move the 3D colposcope freely while operating.

After testing all devices and supporting components together, we will assemble them all. Therefore, the overall system will consist of a monitor stand, 3D monitor, metal box, laptop, shelf, articulated arm, mouse and keyboard, 3D colposcope, basket, and footswitch.

CHAPTER 4
EXPERIMENTAL RESULT

This chapter describes the result of creating the hardware section and developing the software section. This chapter consists of 6 sections, following chapter 3 consisting of endoscope development, hardware design and manufacture, 3D visualization system development, real-time object detection development, GUI development, and system assembling.

4.1 Result from endoscope development

4.1.1 Camera Selection

After finding the camera suitable for this research, the camera should provide high resolution. The camera's diameter should not be large since the hardware must consist of 2 cameras for making 3D image systems. Therefore, the 3In1 HD1200P Endoscope is the CMOS endoscope that is suitable for receiving high-resolution images, and it has small size enough to be constructed and inserted into the vagina. The endoscope, as shown in Figure 4.1 and its specifications are:

- Camera head outer diameter: 8 mm.
- View angle: 70 degrees.
- Focal distance: about 6 cm.
- Resolution: 1600 * 1200 pixels.
- Light: 8 pcs Adjustable White Light Emitting Diode (LED).
- Frame Rate: 16 fps.
- Field of View: 7 * 9 cm.

Figure 4.1 CMOS endoscope.

4.1.2 Camera calibration

In the camera calibration method, 2 CMOS endoscopes were calibrated with two properties which are distortion and illumination.

4.1.2.1 Distortion calibration

The distortion of each endoscope was calibrated using the MATLAB program by analyzing the checkerboard images taken by 2 CMOS endoscopes at many perspectives. The result from MATLAB can tell that both CMOS endoscopes are not distorted, as shown in Figure 4.2.

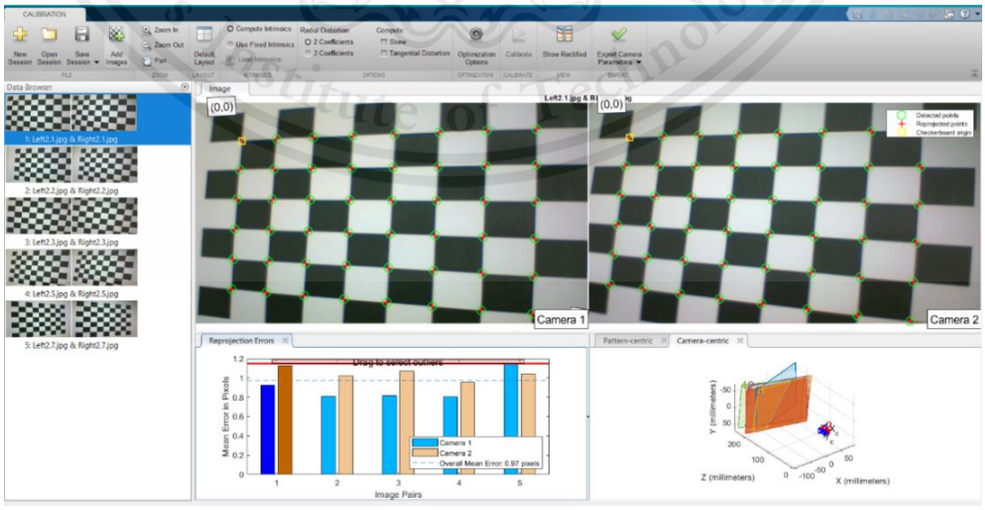

Figure 4.2 Distortion calibration of 2 CMOS endoscopes.

4.1.2.2 Alignment calibration

The alignment of both endoscopes was calibrated using the MATLAB program to analyze the checkerboard images taken by 2 CMOS endoscopes from many perspectives. MATLAB results can tell that the 2 CMOS endoscopes are aligned in the same plane, as shown in Figure 4.3.

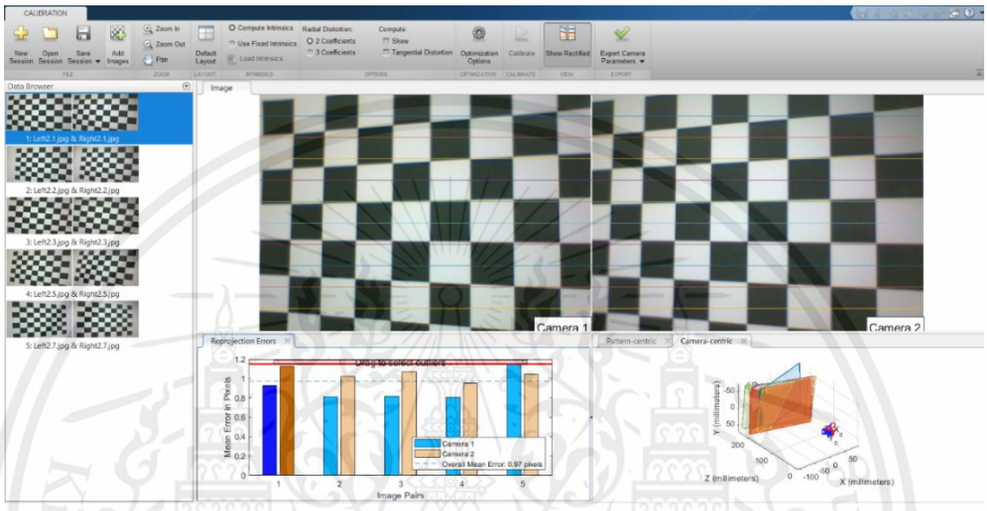

Figure 4.3 Alignment of 2 CMOS endoscopes.

4.1.2.3 Illumination calibration

The illumination of the endoscope was calibrated by using a power meter. Each CMOS endoscope measured the illumination in the darkroom five times and calculated the average values shown in Table 4.1. The result is the left endoscope can give higher illumination than the right endoscope around 0.78 μW.

Table 4.1 Illumination calibration of 2 CMOS endoscopes.

No.	Illumination ($\boldsymbol{\mu W}$.)	
	Left	Right
1	41.4	40.7
2	41.5	40.7
3	41.5	40.7
4	41.5	40.7
5	41.5	40.7
Average	41.48	40.7

4.2 Result from hardware design and manufacture

After designing the hardware, it was made, as shown in Figure 4.4. The camera encapsulation part is made from stainless steel 316LVM, and the handle part is made from ABS plastic which both are medical-grade material. The 2 CMOS endoscopes insert into the encapsulation tube part, which is parallel and aligns in the same plane, as shown in Figure 4.5.

Figure 4.4 Real hardware product.

Figure 4.5 Front view of the camera encapsulation part.

4.3 Result from 3D visualization system development

After making 3D polarized imaging using python code to concatenate two images received from 2 CMOS endoscopes in the horizontal direction, the result displayed by the program is shown in Figure 4.6. To see 3D polarized image, the user

has to use the 3D monitor with 3D polarized glasses. Then, the user can see 3D polarized image, as shown in Figure 4.7.

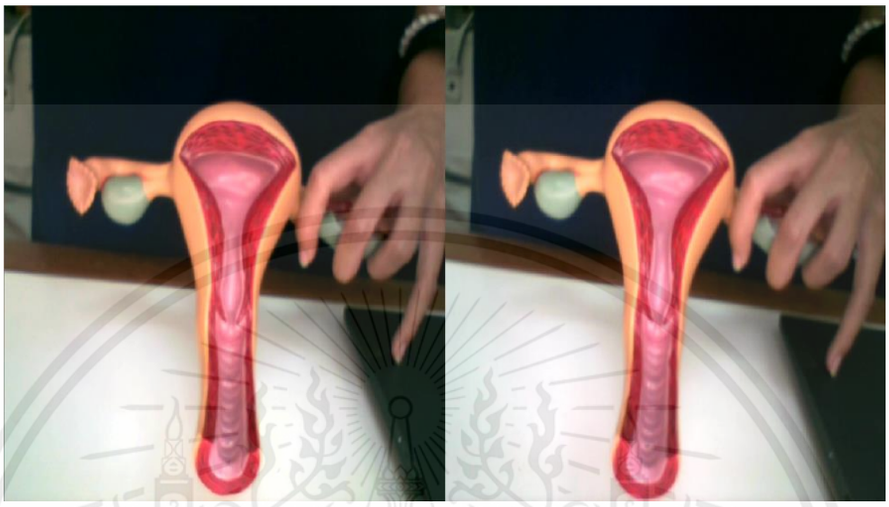

Figure 4.6 The concatenate in horizontal of 2 images.

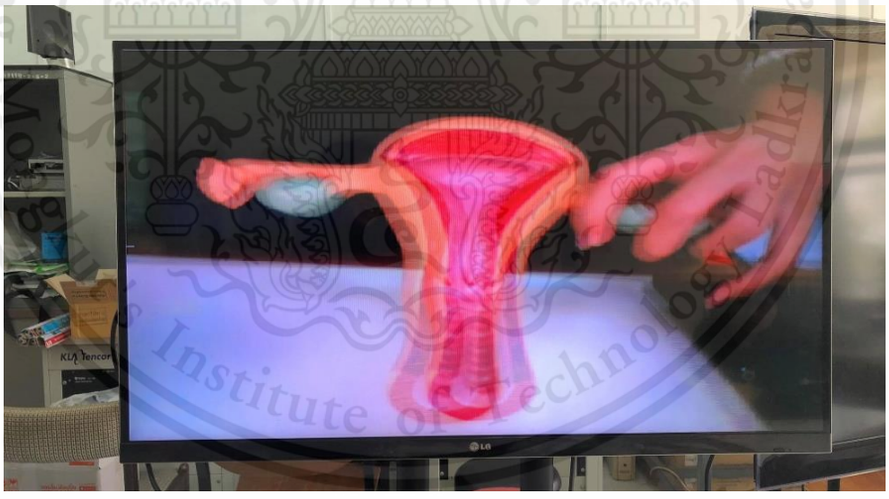

Figure 4.7 The polarized system with a 3D monitor.

4.4 Result from real-time object detection development

4.4.1 Deep learning development

4.4.1.1 Model training

From the model training method, we have done many times and received many models. Each model shows its essential values in the form of a graph, as shown in Figure 4.8. These values will be taken into account when deciding which model is suitable for further testing.

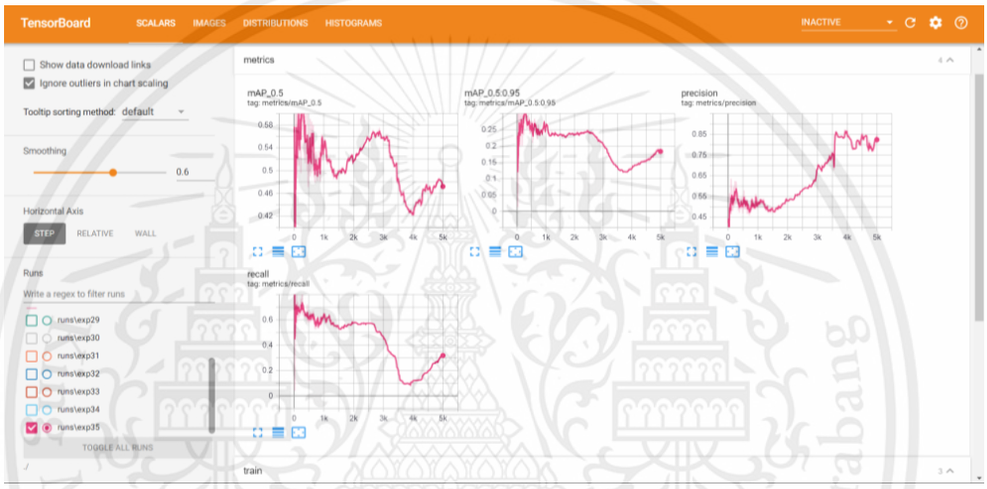

Figure 4.8 The result of model training.

4.4.1.2 Model testing

After selecting the model that can predict cervical cancer, each model was tested by a set of images to measure the performance when facing images that have never been seen before. The model can predict the cervix image to be normal or abnormal following the trained classification, as shown in Figures 4.9 and 4.10.

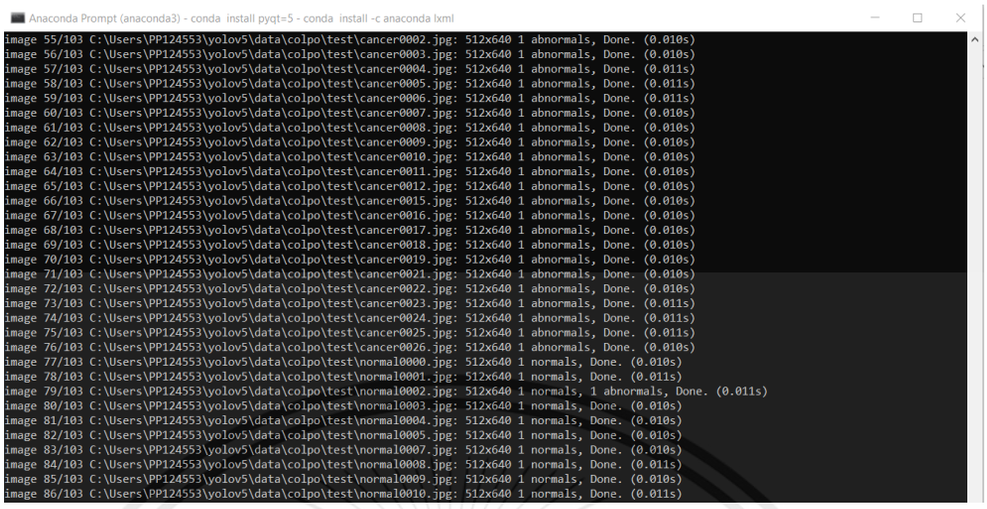

Figure 4.9 The result of model testing in command prompt.

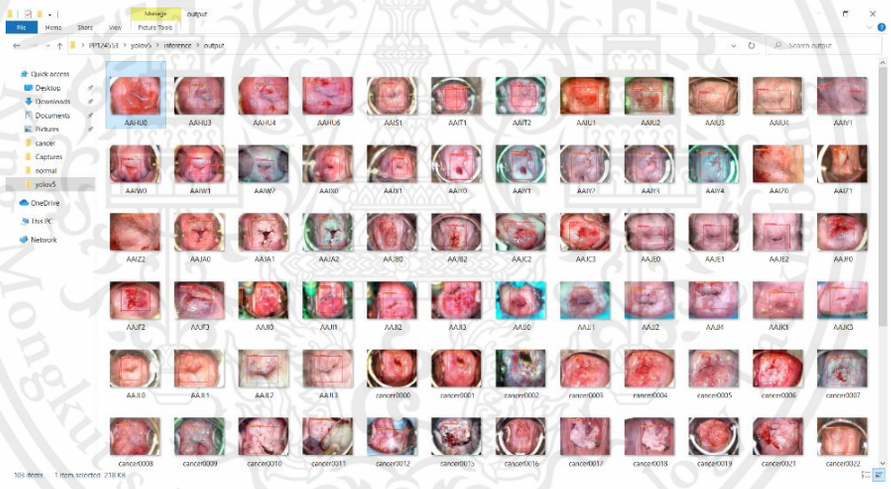

Figure 4.10 The result of model testing is saved in the folder.

4.4.2 Confusion Matrix and ROC curve

After testing the model, many values are recorded following the confusion matrix: TP, TN, FP, and FN. Then, these values are used to calculate the sensitivity, specificity, accuracy, negative predictive value, and precision, as shown in Table 4.2.

Table 4.2 Value calculated from the confusion matrix.

Model	Confusion Matrix				Calculation				
	TP	FP	TN	FN	Sensitivity	Specificity	Accuracy	Negative Predict Value	Precision
1	46	4	11	31	0.920	0.260	0.620	0.733	0.597
2	41	9	26	16	0.820	0.620	0.728	0.743	0.719
3	37	13	32	10	0.740	0.760	0.750	0.711	0.787
4	32	18	37	7	0.640	0.840	0.734	0.673	0.821
5	29	21	36	8	0.580	0.820	0.691	0.632	0.784
6	22	28	34	8	0.440	0.810	0.609	0.548	0.733
7	43	7	22	20	0.860	0.520	0.707	0.759	0.683
8	35	15	17	27	0.700	0.390	0.553	0.531	0.565
9	26	24	34	8	0.520	0.810	0.652	0.586	0.765
10	35	15	27	15	0.700	0.640	0.674	0.643	0.700

From the table, we plot the relationship between sensitivity and 1-specificity to compare with the ROC curve shown in Figure 4.11 to see how effective the model can separate between normal and abnormal cervix tissue. The model that has the closest point to the perfect classifier point is the most effective model that may be suitable for real-time system implementation.

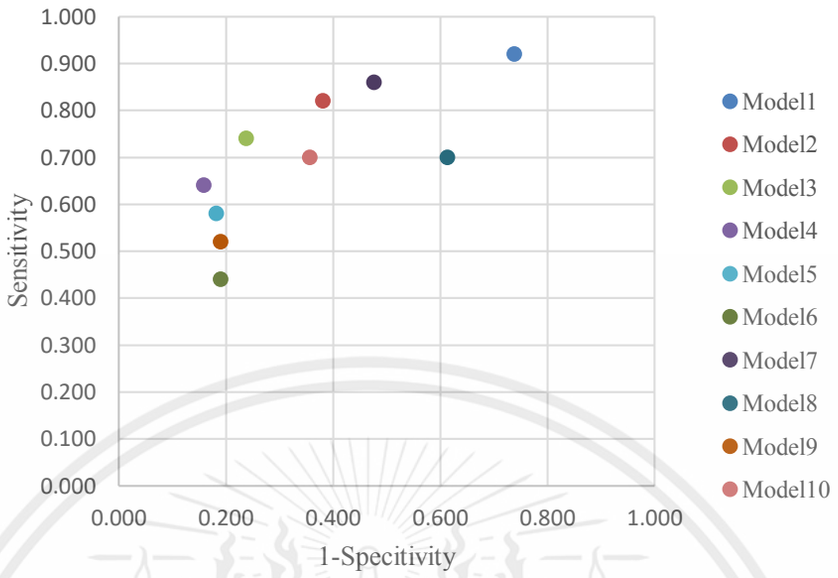

Figure 4.11 Relationship between sensitivity and 1-specificity of many models compared with ROC curve.

4.4.3 Real-time object detection

The most effective model from comparing with the ROC curve will be used in the real-time cervical cancer diagnosis system. The system predicts by displays a rectangular frame surrounding the area in the cervix image that is normal or abnormal, as shown in Figure 4.12.

Figure 4.12 Real-time object detection.

4.5 Result from graphic user interface development

The GUI of the system is written using Tkinter. It consists of 2 pages. The first page is for adding patient's information, as shown in Figure 4.13. The second page for selecting the user's required mode is shown in Figure 4.14. This page consists of 4 modes: normal mode, AI mode, polarized mode, and fluorescence mode.

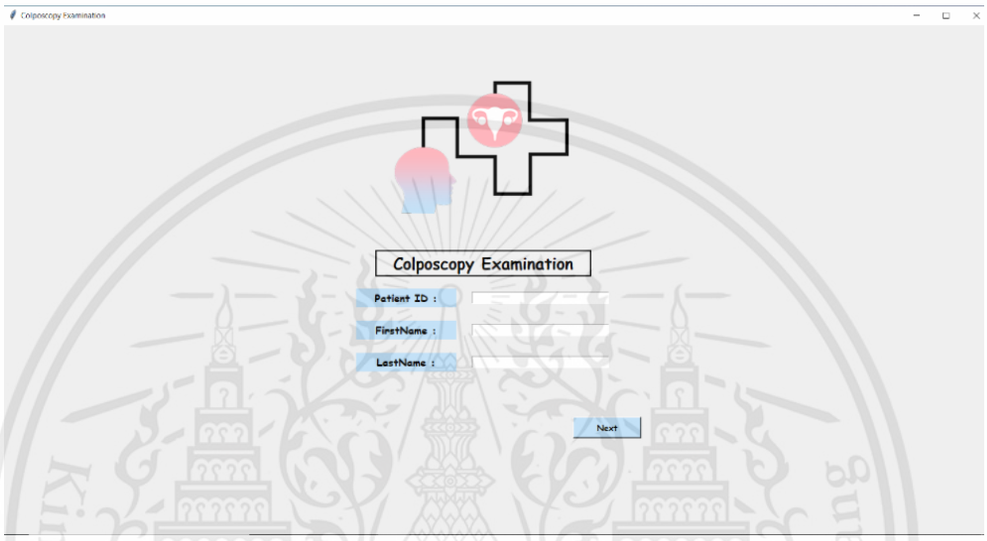

Figure 4.13 First page of the GUI.

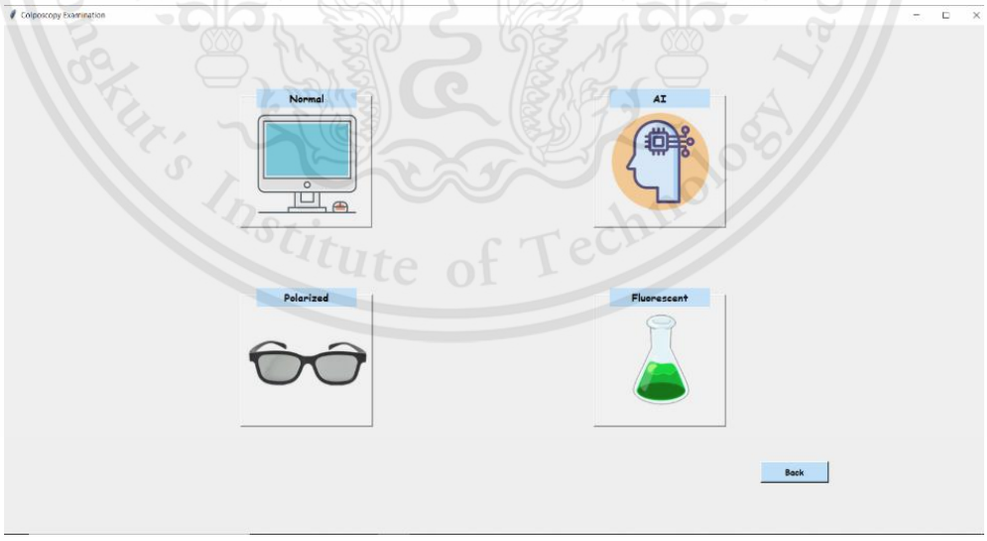

Figure 4.14 Second page of GUI.

4.6 Result from system assembling

After developing the hardware section and software section, we designed and ordered some additional parts for carrying components. These include the footswitch, articulated arm, shelf, basket, and metal box, as shown in Figure 4.15.

Figure 4.15 Overall of the system.

CHAPTER 5
DISCUSSION AND CONCLUSION

In this chapter, we first discuss the result from chapter 4, which consists of 6 parts. Then, we conclude the key concepts that are the purpose of this research. Next, we list the problems we have experienced, including the possible solutions for solving the problems. Finally, we think about the future work which can improve this research to be better.

5.1 Discussions

5.1.1 Endoscope development

The camera used is a CMOS endoscope with 8 mm. diameter, a small size to reduce invasion and pain in cervical cancer diagnosis. The resolution is 1600*1200 pixels, which are HD level, providing sharp and clear images to improve a doctor’s diagnosis's efficiency.

The distortion calibration and alignment calibration of the endoscope using the MATLAB program shows that the image obtained from both CMOS endoscopes is not distorted, and both CMOS endoscopes are in a straight alignment but not 100% alignment. It was done by manual alignment, causing an error in setting the camera to align exactly.

The endoscope's illumination calibration using a power meter shows that both 2 CMOS endoscope illuminations are slightly different. Because the environment during measurement is not a dark room entirely, it has external light interference that may affect the measurement.

5.1.2 Hardware design and manufacture

The device consists of 2 parts. The first part is the handle, which has been designed to fit the hand's size to grip firmly and convenient to use. The material used is ABS plastic, a type of medical-grade material widely used in medical devices. The second part is the camera encapsulation, designed to be a long tube with a small diameter to reduce invasion and pain in cervical cancer diagnosis. The tube has been designed to be 20 cm. long, which is suitable for the patient's vaginal length,

approximately 10-15 cm. long. The material used is Stainless steel 316LVM, a type of medical-grade material widely used in medical devices. Lastly, the angle between the two parts is designed to tilt downwards about 20 degrees to fit the degree that the doctor uses while operating.

5.1.3 3D visualization system development

In developing a 3D visualization system, we decided to create the 3D image with a polarized system. This system needed to be used with 3D polarized glasses and 3D monitors to see the 3D image. The image will be stereo with a greater depth than the normal image causing the doctor to see the picture more realistic and help in the doctor's diagnosis. However, this visualization 3D system may not be suitable and accessible to all locations since it is necessary to have a certain distance of view to see the image in 3D. Therefore, there are limitations for smaller locations that may not be suitable for using 3D visualization systems. The image obtained from the 2 CMOS endoscopes has a slightly wide distance between images, which causes the 3D image not to become a single image and still see the overlapping between 2 images. The reason is the distance between 2 CMOS endoscopes that align together is not close enough.

5.1.4 Real-time object detection development

A real-time object detection system can determine the cervix's position that is normal or abnormal. The system has sensitivity, specificity, precision, negative predictive value and accuracy at 0.74, 0.76, 0.787, 0.711 and 0.75, respectively.

To compare the performance of the system with the normal colposcopy, we refer to the Clinical research of Analysis of Sensitivity, Specificity, and Positive and Negative Predictive Values of Smear and Colposcopy in Diagnosis of Premalignant and Malignant Cervical Lesions: sensitivity, specificity, positive predictive value and negative predictive value of colposcopy were found to be 0.92, 0.67, 0.52 and 0.96, respectively [22].

From the clinical research, our system has similar values, but some values are slightly lower. The reason is the number of cervical images taken for the deep learning system is relatively small. Since the patient needs to be permitted personal information, the system still has insufficient knowledge to perform as the researcher expected.

5.1.5 Graphic user interface development

The GUI consists of 2 pages, which are not complicated because doctors require a device that is quite convenient for work to make a quick diagnosis for the patient. Therefore, the GUI will allow users to use it conveniently without going through many steps. The information entered in the GUI will create folders and store patients' images during diagnosis.

5.1.6 System assembling

Overall of the system consists of several components: laptop used to run the system, which is folded into a metal box to reduce space usage, footswitch which helps to capture and save images at runtime, and to quit from the program without users having to use hands to operate. The system also consists of large components: a 3D monitor for displaying during diagnostic work, articulated arms for carrying keyboard & mouse that use instead of laptop and carry 3D colposcope that is the main device. These arms can move freely. The last component is a stand for holding all the components of the system together. So, the system's overview is quite large, which can make it difficult to transport and requires a lot of space to install the system.

5.2 Conclusions

The 3D colposcope is designed and manufactured using medical material, consisting of 2 parts: handle and camera encapsulation. The angle between the two parts is designed to be tilted downwards for the convenience of doctors. The 3D colposcope will be used with an articulated arm to control moving direction and keep it stationary. This combination will help to provide more stability in AI performance. Using a footswitch to capture the image and exit the program will help doctors be more convenient.

The 3D visualization system can visualize the image's depth, which is obtained using the 2 CMOS endoscopes to make a stereographic system. This system aligns both endoscopes in the same plan and calibrates the camera's features to the best matching.

The artificial intelligence system has been learned using images of the cervix by relying on deep learning. Testing many models has compared the performance with the ROC curve for selecting the best model. Therefore, the performance of the best model for this system is 75.0%.

5.3 Problems and solutions

- The CMOS endoscope has some good enough features, such as resolution and frame per rate (FPS) not high enough. The result is video is a little bit slow and not smooth. Therefore, we should find a new CMOS endoscope with higher resolution and FPS to receive more details of images and display video smoothly while operating.
- Both CMOS endoscopes are not exactly aligned and have a tiny gap between them, sometimes causing the user to see two overlapped images instead of a single 3D image. Therefore, we should align both endoscopes to be exactly as possible for receiving two images with the same angle of view. Besides, we should find an appropriate distance between 2 endoscopes that can be creating the best 3D image.
- Artificial intelligence has less amount of image data to train the system, causing accuracy in diagnosing the cervix is not high enough. Therefore, we should increase the amount of image data and increase image data variations to increase the accuracy and performance of the system.
- The overview of the system is quite large. It may use a lot of space to install the system, and difficult for a doctor to control it. Therefore, we should design and develop to be smaller but remains strong to facilitate doctor while operating.

5.4 Suggestions

In the future, artificial intelligence systems will be developed to be more accurate by increasing the amount of cervical image data used for training in the system. It may be possible to cooperate with many hospitals and ask patients to use their images to develop the system. Suppose there is enough variety of cervical images. In that case, AI may be developed to diagnose cervical cancer to the class of severity, which is a more detailed diagnosis and can be used by doctors to make decisions in cervical cancer diagnosis.

The 3D colposcope may be developed to be smaller and lighter by replacing the endoscope with a smaller diameter for greater convenience. It may include modifying the device's shape after receiving the user's feedback to be a more comfortable holding device.

The 3D polarized system may be developed to visualize without wearing 3D polarized glasses.

Besides, the overall hardware system will be developed to be smaller. It will be able to move more easily, and it does not require a lot of space for system installation, as some hospitals have limited usable space.

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