Technology supporting health services for rural areas based on image processing

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Abstract. Limited health facilities, both medical equipment and health workers in developing countries and other rural areas in the world, bring significant problems for public health services. In order to make a correct diagnosis, it is necessary to support accurate data from health equipment that should be available at the health care centre. On the other hand, the development of technology, especially in the field of digital image processing is quite rapid. This paper discusses the application of digital image processing in solving problems concerning the limitations of health care facilities. In this paper, we will discuss the application of digital image processing in cataract screening, image quality improvement of ultrasonography, identification of leukocyte cells, and identification of ventricular areas and the hippocampus of magnetic resonance imaging images. The results show that the implementation of digital image processing techniques can help overcome some of the problems that arise due to the limitations of these health facilities.

1. Introduction
Indonesia, as a big country, certainly has significant consequences in various problems. Starting from economic problems, social-political, education, and health. In the case of health, access to health facility services is essential. In providing health services to the public, it is needed technology facilities supporting health services, including supporting technology for the diagnosis of doctors. At present, there is much available health support technology that can provide accurate information for doctors in providing a diagnostic decision. Some diagnostic support tools currently available include ophthalmoscope, slit-lamp camera, flow cytometry, magnetic resonance imaging, ultrasonography, and many more. Flow cytometry is a device that can provide rapid analysis of a cell, both in the form of quantitative and qualitative information. Many hospitals, especially hospitals, because the information obtained is quite complete such as complete blood information, bone marrow, serous cavity fluid, cerebrospinal fluid, urine, and solid tissue. Also, this device can be used to measure characteristics in the form of cell size, cytoplasmic complexity, DNA and RNA content, and various membranes and intracellular. These variables are instrumental in hematology applications. With such a great function, flow cytometry becomes an important laboratory instrument in a hospital [1].

The ophthalmoscope is a device used to examine the inside of the eye. This device is beneficial for assessing the state of the retina, the inner eye lining, which contains light-stimulating recipient cells. This equipment is widely available in hospitals and small health service units. However, the user must be someone who does have competence in terms of eye health [2]. Slit Lamp cameras are cameras that utilize the use of a high-intensity light source that can be focused to shine a thin sheet of light onto the...
eyeball. It is used in conjunction with a bio microscope. The lamp facilitates examination of the anterior segment, or frontal structure and the posterior segment of the human eye, which includes the eyelids, sclera, conjunctiva, iris, Crystal lens, and cornea. The binocular slit-light examination provides an enlarged stereoscopic view of the eye structure in detail, allowing an anatomic diagnosis to be made for various eye conditions. Both hands holding the lens are used to examine the retina. The primary function of this type of camera is to check for diseases/abnormalities in the eye that cannot be seen with the naked eye; some interpret the same as an eye microscope.

The patient's eyes will be given a high-intensity light source that is focused on the eye. The examination includes the eyelids, sclera, conjunctiva, iris, crystal lens, and cornea. The slit-lamp examination provides a magnified stereoscopic view of the structure of the eye in detail, allowing an anatomic diagnosis to be made for various eye conditions: Chlora, conjunctiva, iris, crystal lens, and cornea. The slit-lamp examination provides an enlarged stereoscopic view of the structure of the eye in detail, allowing an anatomical diagnosis to be made for various eye conditions [3]. Ultrasonography (USG) is an examination in the field of diagnostic support that utilizes ultrasonic waves with high frequency in producing imaging, without using radiation, not causing pain (non-traumatic), does not cause side effects (non-invasive). Ultrasonography utilizes ultrasonic waves, which are electromagnetic waves, to assist health workers (doctors or midwives) in diagnosing diseases or detecting what is in the patient's body. Ultrasonography in the field of health aims to examine the organs of the body that can be known as the shape, anatomical size, movement, and its relationship with other surrounding tissue. The benefits of ultrasonography are for examining cancer of the liver and brain, seeing the fetus in the womb of a pregnant woman, seeing the movements and development of a fetus, detecting differences between soft tissues in the body, which cannot be done by x-rays, so that they are able to find tumors or soft lump in the human body. In addition to the benefits above, ultrasonography is used to monitor blood flow rates. Ultrasonic pulses with a frequency of 5-10 MHz are directed toward the arteries, and a receiver will receive a scattering of reflected wave signals.

The frequency of reflection will depend on the movement of blood flow. The aim is to detect thrombosis (narrowing of blood vessels) that causes changes in blood flow rate. Ultrasound examination is safer than examination using x-rays (X-rays) because the ultrasonic waves used will not damage the material being passed while the x-rays can ionize living cells. Because ultrasonic is one of the mechanical waves, ultrasound examination is called non-destructive testing. Another application of sound waves in medicine is the use of ultrasound for cancer and liver cancer. Also, ultrasonography can measure the depth of an object below the surface of the skin through the time interval emitted until the ultrasonic waves are reflected [4]. Magnetic resonance imaging or MRI is a medical examination that uses magnetic technology and radio waves to see details of human body parts. This tool can be likened to a scanner, which can see and examine the organs in the human body. Almost all parts of the body can be examined by performing an MRI examination, such as parts: Brain and spine, bones and joints, Breasts, Heart and blood vessels, various organs in the body such as the liver, uterus, bladder, or prostate gland. MRI examination is different from X-ray examination that uses x-rays that can be harmful to the health of the fetus and child. This examination is safe enough for pregnant women and children to use because it uses magnetic technology and does not cause any pain [5]. Referring to instruments, as explained before, it can be seen that the instrument has a very extraordinary function in supporting the diagnosis of doctors. However, unfortunately, the instrument has several weaknesses in its application, including the price, which is quite expensive, and the resources that operate it require special competence.

This condition will not be a problem for health services in developed countries or large cities which generally have excellent infrastructure in all health service facilities and the availability of competent human resources in the health sector. However, this will be a big problem for developing countries and rural areas which are still widely available throughout the world, as happened in Indonesia. Indonesia is an archipelago with more than 17 thousand islands. With the geographical conditions of these islands, each of these regions inevitably has different economic and social conditions. In terms of health, the distribution of health facilities and services is also uneven, including human resources. On the other
hand, as part of a country, the Indonesian people are entitled to the same health access services in all regions. In reality, these conditions are challenging to realize. This condition happened is due to economic factors, the availability of human resources, and geographical conditions.

On the other hand, the development of information technology is growing rapidly. One part of this information technology is the development of digital image processing. Image processing is digital image processing, especially by using a computer, into better quality images. Image Processing aims to improve the quality of the image so that it is easily interpreted by humans or machines (in this case, computers). Image processing has a comprehensive application in various fields of life, such as in the military, trade, medicine, biology, law, robotics, and others [6]. Referring to this condition, this paper will discuss the application of digital image processing in solving problems regarding the limitations of health facilities and services in rural areas and developing countries.

There is much research that discusses the use of digital image processing in the medical field. Thirumaran [7] provides information on basic concepts and technology in medical image processing based on image processing in general. Dougherty [8] reviewed several research applications on medical images using algorithms and techniques in digital image processing. Aiello [9] discussed the role of digital image processing in exploring all information from a medical image in a big data analysis. Marques [10] discussed the potential use of artificial intelligence in medical image processing as part of a diagnosis. Sprawls [11] conducted a review of the structure and characteristics of medical images on image quality, including contrast, image details, and noise. Sudha [12] discussed in detail about medical image processing methods as well as various medical image modalities that exist today, including X-ray images, CT scans, MRI and ultrasonography. He also discussed optical modalities such as endoscopy, photography, and microscopy. Rastgarpour [13] discussed the application of artificial intelligence in the segmentation of medical images according to available modalities. Litjens [14] reviewed the concept of learning about the various contributions of digital image processing, pattern recognition, and machine learning in various areas of medical imagery. Patra [15] discussed the development of two new techniques for improving image quality based on mathematical morphology in overcoming the problem of the limitations of the function of morphological filters in medical images.

In this paper, we will conduct a review of the research we have done before, especially in the field of digital image processing, which is applied in the medical field. The research that we have done previously includes the application of digital image processing techniques in cataract screening, improvement of the quality of low-resolution ultrasound images, identification of leukocyte cells based on microscopic images, and segmentation of the hippocampus and ventricular areas in MRI images to help establish the diagnosis in Alzheimer's disease.

2. Methods

Basically, in this sub-section, we divide the method based on the results of our previous research, as we have stated in sub-section one above.

2.1. Cataract Screening

In this section, we will discuss the development of a cataract screening system based on image processing techniques that we have already done [16] [17] [18] [19] [20] [21] [22] [23]. In principle, the method used in the development of this device is straightforward. Patients are only asked to sit and take photos of their eyes using an ordinary digital camera. Then the photo is included in the software that we developed to be analyzed automatically, and the screening results come out immediately. Figure 1 shows the steps in how this procedure is carried out.
Referring to Figure 1. In principle, the patient is asked to sit in a relaxed manner, then the doctor or an ordinary person takes a photo of the patient's eye with a focus on the pupils of the eye. Figure 2 shows the implementation of the application of this method.

After conducting the data acquisition, as in Figure 2, the digital images obtained from the acquisition are analyzed using the system that we have developed. The flow chart showing the screening process is shown in Figure 3.
2.2. Image Enhancement on low-resolution ultrasound

We have researched in this field before [25] [26] [27] [28] [29] [30] [31] [32] [33] [34] [35]. The main objective of this research is to make improvements in low-quality ultrasonography images as is well known that many regions in developing countries such as Indonesia do not yet have adequate health facilities or sometimes even none. Ultrasound machines are one of the most crucial diagnostic support devices. This tool can be used as a reference to strengthen the diagnosis of doctors, especially internal medicine, including the diagnosis of pregnant women and the development of the fetus in it. A brief description of the whole system is shown in Figure 4.

![Figure 4 General Description of Image Enhancement on low-resolution Ultrasonography](image)

Refer to Figure 4. The general description carried out in this section is as follows. Patients perform scanning using low-quality ultrasonography available in rural health service units, including several regions in developing countries. The results of the ultrasonography image are then scanned using a printer scanner that is commonly available in the community to produce a digital image. For the record, ultrasonography machines in some rural areas have not been automatically digitized. Furthermore, the digital image has been improved using digital processing techniques to become a higher quality image. So based on the improved digital image, this image can be further processed to segment the desired area, so that it can be used for various purposes such as automatic measurement of fetal length, detection of uterine abnormalities, etc.

2.3. Identification of Leukocyte Cell Based on Microscopic Images

Research in this area is also carried out as an effort to resolve the limitations of health facilities in rural areas. This condition is motivated by the importance of the existence of blood analysers such as flow cytometry and the presence of pathology specialists in analysing all information contained in blood cells. Similar to what has been explained in subsection 2.2, many rural areas do not yet have flow cytometry or pathology doctors. We have conducted several studies using image processing techniques to overcome this problem [36] [37] [38] [39] [40], and this research is still ongoing. General description of this system is shown in Figure 5.

Refer to Figure 5. In this study, we currently concentrate on identifying leukocyte blast cells. From an ordinary microscope, we took photos of blood cell preparations using an ordinary digital camera so that it could become a digital image. Furthermore, we explored the digital image both on the cytoplasm and the nucleus. At this time, we are only able to explore the morphology of images, including the width, diameter, and circumference of the blast cell. In addition, we have also successfully exported statistical texture values.
2.4. Image processing application in Alzheimer's disease

Research on the application of image processing in Alzheimer's disease is still in the initial process [41], [42], [43], [44]. As with the three previous studies, the ultimate goal of this study is to improve the quality of the MRI image of low quality, so that it can be used to automatically identify the severity of the disease for people with Alzheimer's. General description of this system is shown in Figure 6.

Referring to Figure 6. The image of the scanned magnetic resonance imaging (MRI) there is three types of slices, namely Sagittal, Axial, and Coronal. Then the image is made as to the input image of our system. From the system it can be processed to strengthen the image for quality improvement, then segmentation for the hippocampus and ventricles is done.

The morphology of the two regions is then automatically measured. At this time, the new process arrived here. Future research will concentrate on a more in-depth exploration of all variables of the ventricles and hippocampus so that they can be used as reference values for the classification of each patient's condition.
3. Results and Discussions

3.1. Cataract Screening System

As explained in sub-section two above, research on cataract screening was carried out by us a few years ago [21][17] [16] [45] [22] [19] [18] [20] [46] [23] [47] [48]. In research on cataract screening, we applied the use of specular reflection in identifying the severity of cataracts in patients. Figure 7 shows the input image input, along with the existence of specular reflection, which can be used as the primary variable for this identification.

![Fig.7. the presence of specular reflections on the pupils of the eye](image)

As discussed in our publication about this research, we use the variable presence of specular reflection in pupils as the main characteristic. Under normal pupillary conditions, there will be two visible specular reflections, whereas, in pupil conditions that are seriously exposed to cataracts, there will only be one specular reflection. We call the more excellent specular reflection a frontside reflection, while the smaller one is a backside reflection. Details about these two things have been discussed in our previous papers. In addition to the specular reflection variable, we also added statistical texture variables which include average intensity and uniformity. In classifying between normal and severe conditions, we use the Support Vector Machine method, and we have also discussed this in our previous paper. The results obtained are a True Positive rate of 92.16 percent and a false positive rate of 18.14 percent.

3.2. Image Enhancement on low-resolution ultrasound

In this section, the main objective is to improve the quality of ultra-sonographic images that have low resolution. Image quality improvement needs to be done because most of the health services in developing countries such as Indonesia have low-quality ultrasound machine quality so that it dramatically affects the diagnosis results. In this quality improvement, we use the Contrast Limited Adaptive Histogram Equalization (CLAHE) method. As discussed in our previous study, the right combination of parameters in the CLAHE method is using the $N_{bins}$ parameter with a value of 256 and the distribution of Rayleigh with an average value of MSE 9744.80 and PSNR 8.284150 [33]. Figure 8 shows an example of quality improvement software using the CLAHE method.
Fig. 8. An example of improvement image quality using CLAHE method

After the image has been improved, we have also developed several applications related to ultrasound images. Among them is the localization of the uterus by image segmentation, automatic measurement of uterine length, measurement of fetal length automatically, and pre-processing for screening for cervical cancer [25][26][28][29][27][30][31][32][33][34]. The results obtained from our previous research are beneficial to be implemented in village health service units in Indonesia.

3.3. Identification of Leukocyte Cell Based on Microscopic Images
Development of microscopic cell-based software aims to build a medical device that has a function as a blood analyser based on digital image processing. This research is still ongoing. For version 01 that we are developing at this time is still focused on the identification of leukocytes cells, although for future research it is expected to be used to analyse cells of all types of blood cells. Starting with the identification of the outer and inner contours of leukocytes, especially blast cells. Then the calculation is automatically suitable for the diameter, circumference, area, and texture of the blast cell. Research shows that the performance of computer aids is promising to be used as a blood analyser for the future. Figure 9 shows an example of the display of a blood analyser tool that we have developed at this time. Regarding the specific performance of the research stages of developing an image, processing-based blood analyser has been discussed in detail in our previous publications [36][37][38][39][40][49].

Figure 9. Example of the main display of blood analyser version 0.1
3.4. **Image processing application in Alzheimer's disease**

Research on this issue is based on reality in a society that not all hospitals in developing countries have MRI machines. Even if there is an MRI machine available at the hospital, it is usually a low-quality MRI machine. One of the causes of the limited number of MRI machines is the high price and maintenance costs. In this field of research, the stages we went through are still in the very early stages. We emphasize the problem of morphological identification for the ventricular and hippocampal areas, which are usually the object of physician investigations in making a diagnosis for Alzheimer's disease. At present, we are only at the stage of identifying these both areas from three types of MRI image slices, namely sagittal, axial, and coronal slices. In our current research, we try to segment and identify the morphological structure of the both areas [44][41][42][43]. It is hoped that by identifying the morphological structure of the three slices, it can be developed to explore more information and classify them according to the severity of Alzheimer's based on the Clinical Dementia Rating (CDR) scale commonly used by doctors in determining the severity of Alzheimer's disease. Figure 10 shows an example of the main display of MRI image-based Alzheimer's identification software that we have developed at this time.

![Example of the main display of MRI image-based Alzheimer's identification software](image)

**Fig. 10. Example of the main display of Alzheimer identification system**

4. **Conclusions**

Referring to the research that we have done previously, as discussed and explained in detail in all the subsections above, it can be concluded that the application of digital image processing is quite promising to overcome problems regarding the limitations of health care facilities in developing countries and rural areas. The main advantage of applying digital image processing techniques to support health care technology is that they are portable, low-cost, easy-to-use, and robust.

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