A mapping mobile robot using RP Lidar scanner

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Mobile Robotics Mapping using RP Lidar Scanner

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Abstract— **The environment mapping in one of the necessary aspects in mobile robotics studies when dealing with localization, positioning, autonomous navigation, as well as search and rescue. Its success depends on the accuracy and reliability of its implementation and may depend on sensors which are used to acquire the environment data. This paper presents work on mapping which uses a low cost laser rangefinder, developed by Robopeak, RP Lidar. This work will be implemented on an autonomous mobile robot for indoor environment applications. Initially, a mobile robot incorporated with the sensor was developed after which a wireless monitoring and control station was established in order to perform data collection of the environments. A research laboratory with tables and equipment is used as a testbed. The collected data were analysed using three methods of pre-processing; i. raw filter, ii. a moving average of smooth filter, and iii. the combination of the raw filter and the moving average. The results show the environment map based on the raw data and the pre-processing performances. The combination of the raw filter and the moving average performs the best result. Besides, the scanning accuracy of the developed system is successful with more than 90% of correctness. As a conclusion, the laser rangefinder and the pre-processing used is capable to map the environment with clear image and hence can be used for a variety of applications.**

Keywords—laser rangefinder; RP Lidar; mapping; pre-processing; mobile robot.

I. INTRODUCTION

Robotic research is a wide area, it covers a large spectrum of different technologies, engineering and applications. The robotic system may turn to a powerful and an excellent support system to human kind, especially in situations where there is hazardous, dangerous and difficult for human to handle. In many situations, it is able to help human work become easier and it may perform the work accurately.

In time, the combination of mobile robot with localization and mapping system is being applied and studied in many applications such as in hospital, home appliances, military, exploration, search and rescue, tracking and positioning. The term localization can be defined as a work to determine and search a position of an object, people or a specific location. Then, the mobile robot localization can be noted as a moving robot that has to work to find a position of a particular target. According to Thrun et al [1], the mobile robot localization is a process of establishing a correspondence between the map coordinate system and the robot's local coordinate system. Mapping can be described as a process to illustrate environment based on the surrounding information which is represented in a graphical image. The map can be presented as a 'metric' or 'topological'. Mapping helps localization by showing the target or object positions in which area the object is located. Also, it helps describing the environment or floor plan. There are many approaches to do environment mapping such as occupancy grid map, topological map, feature, or landmark map and scan map using the raw data.

The challenging issue regarding the mobile robotics mapping is the accuracy and reliability of the sensors. Usually, a mapping work uses cameras, laser range finder, ultrasonic as well as Kinect to be the sensor. These sensors have their own benefits and limitations. For example, the use of ultrasonic will face issues with the blanking interval, speed of sound, angular uncertainty and surface interaction. These problems may cause towards the failure of the whole system, but this can be solved by using multiple sensors in the system. From here, the reliability and the performance of the system can be increased, especially, when one of the sensors are not able or fail to reflect the signal. There are sensors that are highly accurate and recommended, but they are very expensive, especially a laser rangefinder which cost MYR 5000 and above in Malaysia market.

Fortunately, in 2012, Robopeak from China has developed a cheap laser rangefinder which is only cost around MYR 1600 per unit. It is known as RP Lidar. It is easy to implement and attach to any robot system. This laser rangefinder is still considered as a new device compared to SICK and Hokuyo brand. Hence, its application in robotic research is still limited.

Many researches reported have used laser rangefinder in their system for several applications. As reported by R. Wong [2], he used SICK LMS200 laser rangefinder in cluttered and dynamic environment. Roland Philippsen reported that he used SICK type of laser rangefinder to avoid obstacles, motion planning and navigation for his robot tour [3]. Ninad Pradhan used laser rangefinder and other sensors incorporated with a mobile robot for developing a following robot purpose [4]. Many more studied have been conducted using laser rangefinder because it provides accurate and reliable data compared to ultrasonic and infrared [5,6,7,8]. In fact, it also has a wide range of distance achievement with the minimum about four meters and 80 meters the maximum [9]. Usually, the higher of the distance achievement will lead to the higher prices.

The main objective of this study is to map a particular area using RP Lidar, a Robopeak laser rangefinder. It is a low cost laser rangefinder and easy to apply with any mobile robot. The second objective is to analyse the raw data using a few methods of pre-processing. The selected pre-processing does not give the best solutions for the mapping, but, it gives the computational easier and simple. Therefore, it is possible to apply this to a task or work which requires results as quickly as possible or in real time. On the other hand, the simple algorithm in the mobile robot and pre-processing may lead the system to move faster and out with the results instantly.

II. RP LIDAR AND THE MOBILE ROBOT SYSTEM

RP Lidar is a low cost laser rangefinder, 360 degree 2D laser scanner solution developed by Robopeak [10]. The sensor can perform 360 degree scan within six meters range. It scans by applying 5.5Hz when sampling 360 degrees each round. RP Lidar measures a distance based on a laser triangulation ranging principle and it uses high-speed vision acquisition. Mechanically, it emits modulated infrared laser signal and the laser signal is then reflected by the object to be detected. The returning signal is sampled by a vision acquisition system in the RP Lidar. Then, the DSP embedded in the RP Lidar starts processing the sample data and out with distance and angle value between object and RP Lidar through its communication interface.

The RP Lidar is provided with a USB adapter which allows it to communicate with a personal computer. In the personal computer, a software development kit (SDK) is ready to connect with the RP Lidar and display the scanning results as well as save the results of scanning. The scan results will give researcher three parameters which are angles, distances as well as the quality of the results as shown in Fig. 1. The higher value of the quality is better.

For the mobile robot as shown in Fig. 2, it consists of a mobile part (tyre, motor and driver), a computer, power supply as well as a wireless transmitter. The mobile part involves four DC motor gear and driver motors. The power supply was isolated into two categories; i. to support the computer and, ii. to support the mobile part. This part was designed such way in order to keep the computer works longer. The computer part used 24 DC voltages and the mobile part used 12 DC voltage battery. The computer is utilised to establish or make the laser rangefinder function to work wirelessly as well. The AV wireless device is used to let the laser data to be transferred to the main monitor synchronously.

#Angule (θ_{deg})	**#Distance (d)**	**#Quality**
20.7188	5430	11
36.0469	4026.8	10
37.0938	4299.5	11
.	.	.
.	.	.
.	.	.

Fig. 1. RP-Lidar sensor and example of its data.

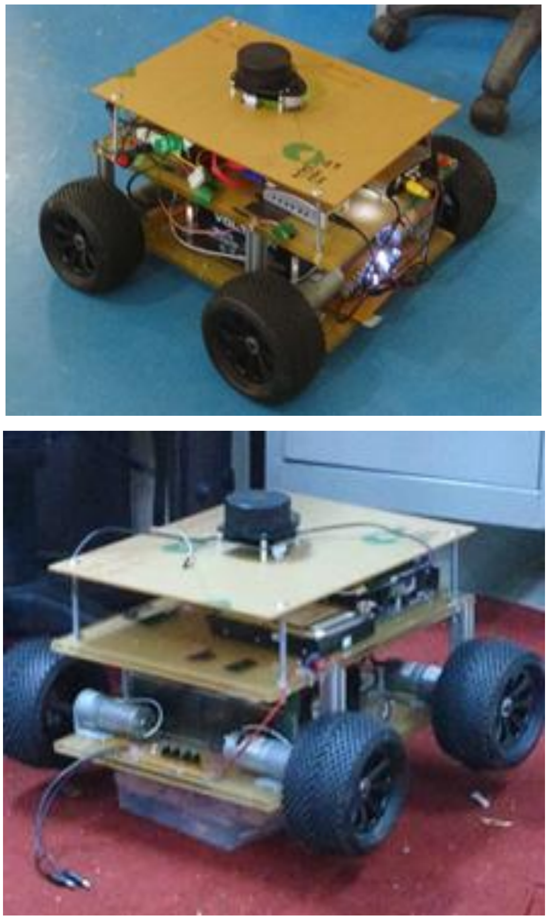


Fig. 2 The mobile robot and RP Lidar

III. Data Collection

Software development kits (SDK) developed by Robopeak has been used to do the data collection as shown in Fig. 3. For data collection, a research laboratory full with tables and equipment is used for the verification of the proposed approach. The area and the brief areas are illustrated in Fig. 4.

Physically, the area has been marked with a few points. The distance between the point and the other point is about 1 meter. On the other hand, the mobile robot was programmed to navigate with the according path, to stop at the particular point and perform scanning as well as to save the data for 30 times for each point. Then, the data are saved in Microsoft Excel file.

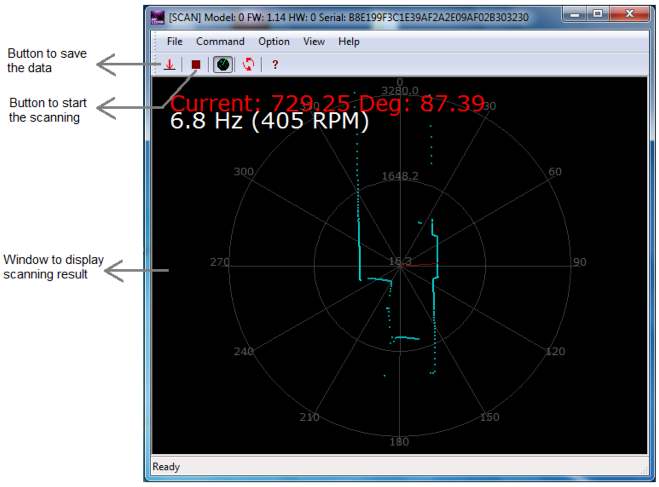
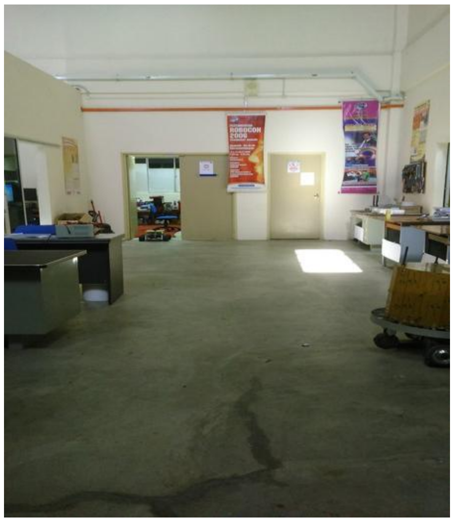


Fig. 3. The SDK for data collection.

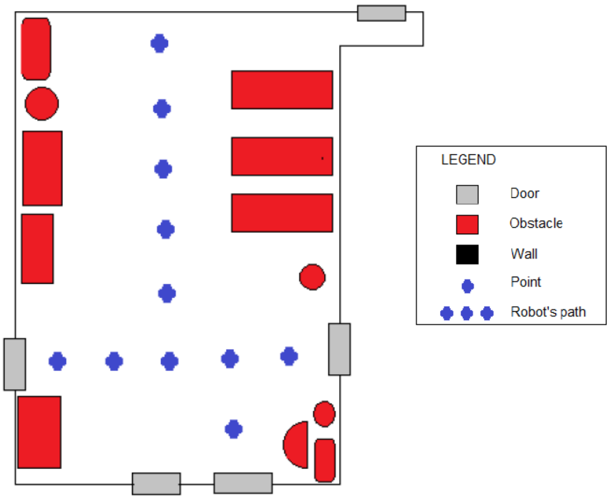
In Fig. 4, the marks in blue colour shows the point that the mobile robot should be stopped for scanning purposes. Also, it shows the path for the navigation of the robot. The areas were marked initially in order to make sure and verify that the mobile robot works according to the program. There are three assumptions defined in this study;

i. The initial coordinate for the mobile robot is (0,0).
ii. The environment map is a global map.
iii. The laser range finder data are performed at stationary positions, because the data do not include compensation for the mobile robot's movement.

(a) i



(a) ii



(b)

Fig. 4. (a) The plan of the experiment area, i. view from front to back, and ii. view from back to front, and (b) The description of the area.

A simple navigation and scanning program is used to instruct the mobile robot. The flow of the program is stated below;

i. The mobile robot takes place at the initial point.
ii. Recognise the point and stop moving.
iii. Do a 360 degree scanning and save the data and repeat 30 times.
iv. Then, move 1 m forward or move right or left depending on the area.
v. Repeat procedure ii and iv till the last point.

IV. THE ENVIRONMENT MAPPING

MATLAB software is used to illustrate the map of the area by using the previous collected data. All points in the area were merged to get the whole map. Then, a raw filter and smoothing method have been used to dismiss all the unnecessary data and restructure the map. For each angle and distance, the x-position and the y-position of the obstacle can be calculated using equations below;

i. Convert the degree to radian

$$\theta_{rad} = \theta_{deg} \times \frac{\pi}{180} \tag{1}$$

ii. Find the x and y

$$x = d \times \sin(\theta_{rad})$$
$$y = d \times \cos(\theta_{rad}) \tag{2}$$

Where θ_{rad} is an angle of the location in radian and θ_{deg} is an angle in degree. x is the position in x-axis and y is the y-axis, this position shows the location of the laser or the mobile robot. The distance value is a distance from the laser to the obstacle and it defines in millimeters unit. After obtaining the x-y positions in each scanning point, the area of the point is plotted by using scattered plot function in MATLAB. Once all the points are plotted, then, the map which used the raw data and the pre-processing results can be displayed.

V. THE RAW FILTER

Raw filter is used to remove overshoot or invalid data. This is not the best solution for image pre-processing, but, it gives simple computation, fast and very practical to a simple mapping application [11]. The filter is designed by setting up the interval between the minimal and maximum of data sensor.

In this study, the minimum value is set to zero while the maximum is set to 6000mm. The interval is set such that, there will be no data that less than zero or negative value. Then, the 6000mm data is set for the maximum because the reliability of the data sensor can be maximised till 6000mm only.

VI. THE SMOOTH FILTER

Beside the raw filter, smooth method also can be said as simple and practical pre-processing. There are a few types of smooth filter, such as moving average, local regression, robust local regression and Savitzky-Golay filter [12]. In this study, the smooth filter performs the small correction using the moving average method where the angle results become the input. At first, the angle is divided into segments, then the average value of the segment is calculated in specific number of period, n.

The example is such below;

Data = [$\theta_{(1)}$, $\theta_{(2)}$, $\theta_{(3)}$, $\theta_{(4)}$, $\theta_{(5)}$],

Then, these numbers will be included into the same segment and will divide by 5. In the other words, the average of the segment will be calculated. The equation is shown as below;

$$\theta_{deg} = \frac{\theta_{(1)\,deg} + \cdots + \theta_{(n)\,deg}}{n} \tag{3}$$

Where θ_{deg} is the output of the smooth filter, n is the value of period and $\theta_{(1)\,deg} + \cdots + \theta_{(n)\,deg}$ is the angle values in a segment. Fig. 5 shows the difference result between the raw data and after processed with smooth method.

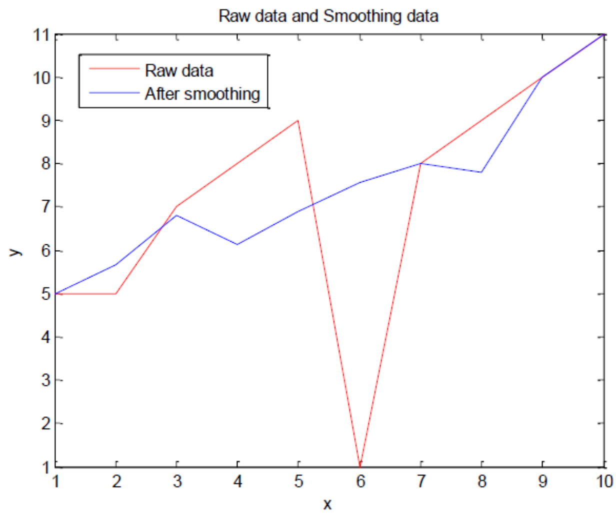


Fig. 5. Example of raw data (red line) and data filtered by smooth – moving average method.

VII. THE SCANNING ACCURACY

In order to verify the reliability of the scanning results, the accuracy of the scanning must be determined. The accuracy percentage is acquired by using the step below;

i. Measure the real area of the environment, Real(x).
ii. Once completed the mapping process, collect a few sample/positions in the map randomly, Npoint.
iii. Calculate the difference between the real position in the environment and the mapping position of the random point. This is to determine the error range

between the real and the scanning value.

Dact_mea(x) = Real(x) – Measure(x).

iv. State a threshold value to regulate the correct values, Xcorr. Any value which is falling in the range will be defined as correct value, otherwise, it is an error value, Xerr. The threshold is set to be ±5 cm.

Xcorr = -5 < Dact_mea(x) < +5

Xerr = else

v. Calculate the number of the correctness, Ncorr.

vi. Calculate the percentage of accuracy by using this equation,

Accuracy % = Ncorr/Npoint x 100%

VIII. Results And Discussion

Fig. 6 (a) to (d) show the results of the research laboratory mapping with the raw data, the smooth method as well as the raw filter. Based on the observation in (b) and (c), the raw filter can remove unnecessary data while the smooth filter may fix the unconnected data. In (d), the combination of the raw filter and the smooth filter shows the map is closer to the original map. It does show the tables, other obstacles and the path in the laboratory.

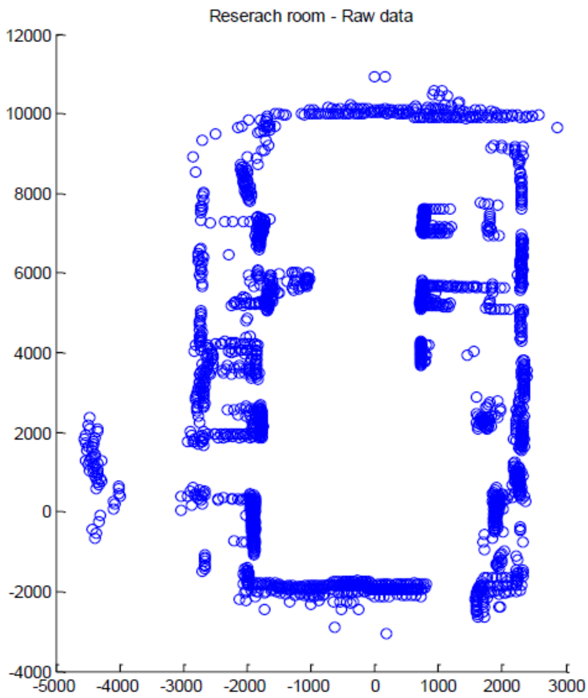
This proves that the simple pre-processing such as the smooth method and the raw filter may present a good result for the map. Since this work does not apply in critical situations, hence, this kind of results with the smooth method and raw filter can be accepted.

The accuracy results of this study as shown in Table 1. The real area of the environment is 5m x 11.8m. The number of sample is collected randomly in the map. The accurate calculation is including the x-axis and y-axis position.

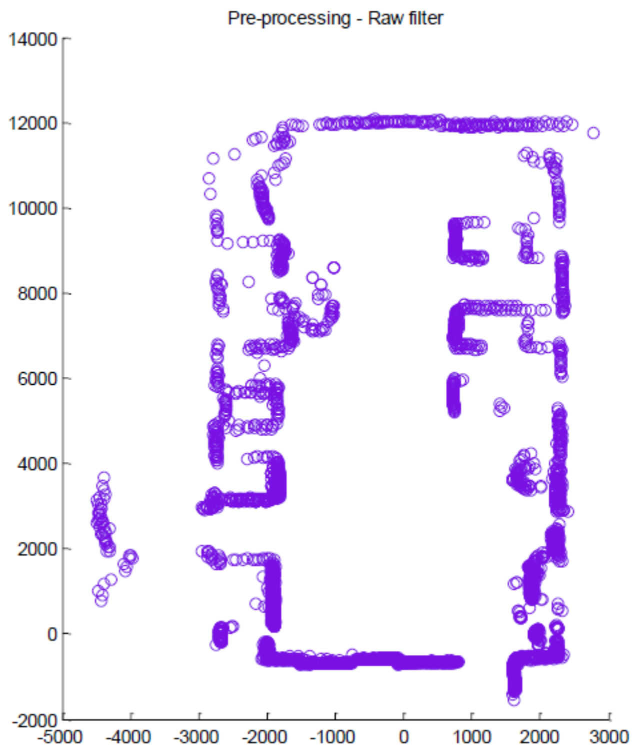
Based on the results, this study shows that the use of the RP Lidar is impressive in terms of its accuracy of scanning. Most of the trials get 90% above of the scanning accuracy. In order to get higher accuracy and reduce the incorrectness, the experiment must be run in particular and standard procedure. The main consideration is when dealing with the mobile robot movement. This is because, the mobile robot usually cannot precisely stop at the particular scanning point. Hence, it definitely leads to a bit of errors in the measurement value.

TABLE I. THE SCANNING ACCURACY RESULTS

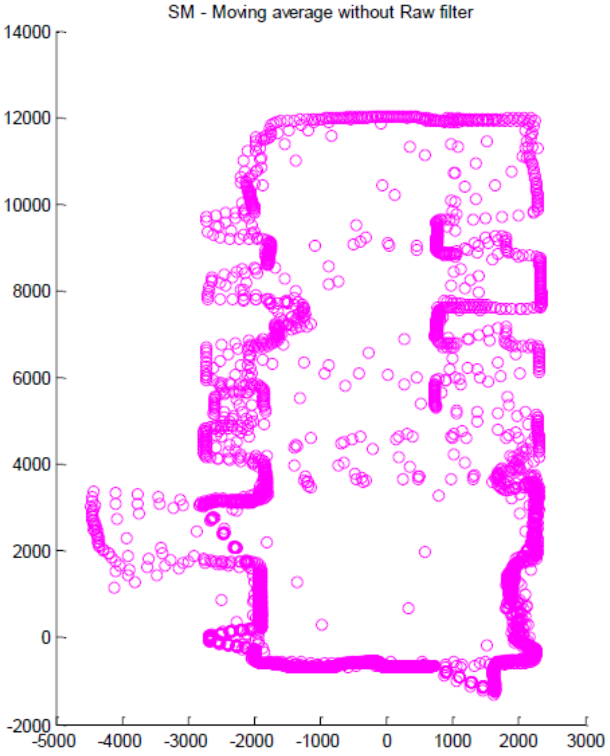
No of trials	No of sample/point (Npoint)	No of error (Nerr)	No of correct (Ncorr)	Percent correct % (Ncorr/ Npoint*100)
1	128	8	120	93.44
2	125	6	119	95.69
3	117	4	113	96.36
4	118	5	113	95.11
5	115	2	113	98.70



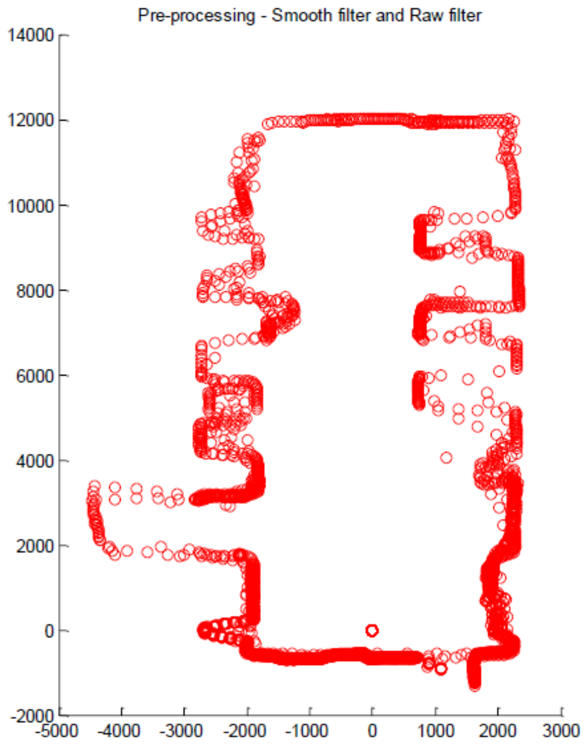
(a)



(b)



(c)



(d)

Fig. 6. The robotic laboratory results. (a) The raw data result (b) The raw filter result (c) The smooth filter with moving average method result (d) The smooth filter with moving average method and raw filter result.

IX. Conclusions

There are many pre-processing methods that can be used in order to improve the performance of laser range finder. Here, the RP Lidar sensor which is the cheapest laser rangefinder in market is used to map the research laboratory environment. Then, the smooth method and the raw filter are used to enhance the performance of the laser data. These pre-processing prove to have simple computational techniques and may solve a task in milliseconds. Also, it definitely can be used to handle unnecessary data and producing good results which can be applied for next processing such as to develop the robot's path or route and a scan matching process. In terms of scanning accuracy, the mobile robot and the RP Lidar is successful with high accuracy which is in five trials of scanning, most of them gave 90% of correctness.

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