Applied Mathematics and Computational Intelligence
In Press, Accepted Manuscript – Note to users

Metal Detector via KNN for Vehicle Robot

Zaidi Lokman Bin Awang[1*], Muhammad Naufal Bin Mansor[2] and Nordiana Binti Sharifuddin[3]

[1,2,3] Faculty of Electrical Engineering Technology University Malaysia Perlis, 02100 Padang Besar, Perlis, Malaysia

ABSTRACT

Through decade of used, several problem occur in conventional metal detector where it become a burden when carried in a long time, the price is so expensive and the user were expose to the threat when using at dangerous site. To solve the problem this research were conduct in to make it lighter, cheap and can be mobilize using remote control. The frequency of different metal was classified via KNN Classifier and the accuracyand sensitivity are higher than 90%.

Keywords: Autonomous, KNN Classifier, Metal detection, Multi-terrain, Microcontroller, Wireless controller.

1. INTRODUCTION

By the definition, metal detector is a device that being used to detect variety type of metal and it can be classified into four types which are security, hobby, industrial and marine search and recovery. From all classification mention the type that widely being use is security type is widely used that can be seen in airports and places that has probability of weapon being smuggled [1]. The concept of detector detects metal is based on pulse induction coil where any disturbance to the pulse caused by the metal will increase the peak voltage and make the sound of buzzer increases. The longest range of metal detection is from hobby type where it can detect almost 3 meter away [2]. The device is portable and required onsite operate.

2. MATERIAL AND METHODS

2.1 Model and Data

Circuit of metal detector were varies to the usage and material use. Several type of metal detector used is Beat Frequency Oscillation (BFO) metal detector and Pulse Induction (PI) detector and Very Low Frequency (VLF) detectors. BFO is change of frequency when the coil detector is oscillate, the detected frequency then were matched with reference oscillator where the oscillation frequency made by the circuit system [3].

BFO type metal detector circuit that is easy to made and use cheap material and component. The circuit requires no integrated circuit(IC) that is hard to obtain locally. Not just that the ranging of the detection can be easily manipulate by varying the coil A(search loop) turns while the coil B(references oscillator) is used to fine tune the frequency and not visible in physical, as it often in the control box. The component used were mostly capacitor, resistor and resistor also a few others. In the figure, the right portion of the circuit is used to control audio output of the speaker while at left side is the important part of metal detection [4].

*zaidilokman94@gmail.com

Next is The Pulse Induction (PI) detector. It is different than BFO metal detector where it sends short magnetic pulse and then producing spark in coil (reflected pulse). The reflected pulse is changing it field shape when get near the metal object, this causing a disturbance and amplification to the pulse, then the output convert into sound or light signal by the circuit [5-10]. This type of metal being use by previous researcher, the detector use single coil type PI detector named „Pulse One Metal Detector". The circuit uses were provided in the G.L Chemelec website and make use of IC 555[11]. The pulse generated is continuously with specified frequency, width, time for the back EMF to decay and time for the system to listen for any induced signals in a target. By adjusting the capacitors and resistors around the integrated circuits can be changed. A transistor goes about as a switch changing the mode of producing signals to listening for signals. The detection system then enhances any sign distinguished and transforms it into a persistent and stable voltage that builds a gradual beat heard in a speaker. Another switch guarantees that the signals intensifier has no yield whilst the curl is creating signals. This alarms the administrator to any objective metals. Batteries are utilized for the force supply and other incorporated circuits to ensure that a relentless voltage is supplied even as the battery is gradually depleted down to a specific point [11].

Very low frequency (VLF) work by delivering a generally low frequency (5-50 kHz) time-changing attractive field with a large (6-12 inch) inductors. A second, smaller coil loop, is protected from identifying any immediate fields prompted by the primary loop, and is tuned to listen for conceivable fields cause of Eddy streams created by adjacent metal items. Based on all classification of the metal detector, the best possible type that can be use in this project BFO detectors because of the inexpensiveness and easy to find components, beside reliable to detect metal underground.

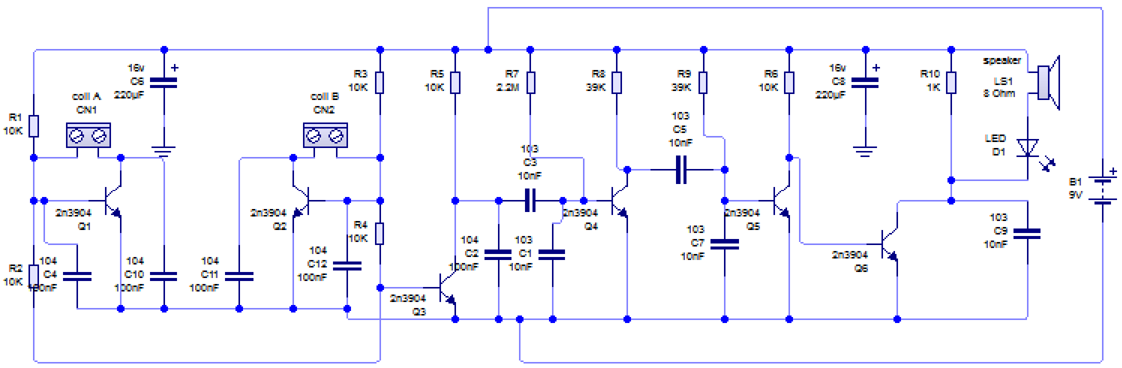

Figure 1. BFO metal detector circuit

2.2 Induction Coil

The coil use in the BFO metal detector were using pulse induction concept where two of the coil were involve. First coil as shown in Figure 2 is used for searching that known as search loop while the other one is the smaller coil that is usually inside the control box, known as the references oscillator. Both of the coil emitting a radio frequency that is necessary to detect metal. By adjusting the oscillators so their frequencies are nearly the same, the difference between coil is made audible to beat sound, where slight change of sound will be heard when it near the piece of metal. It has been found in practice best to make the search oscillator fixed at 100khz and to arrange for the reference oscillator to be adjustable 100khz plus or minus 250hz. This gives a beat note of 250hz to 0 to 250hz. The beat note disappears or nulls when the two oscillators are about equal. This type of detector is most sensitive when the beat note is close to zero, about 5hz (motor boating) any slight change being noticeable [4].

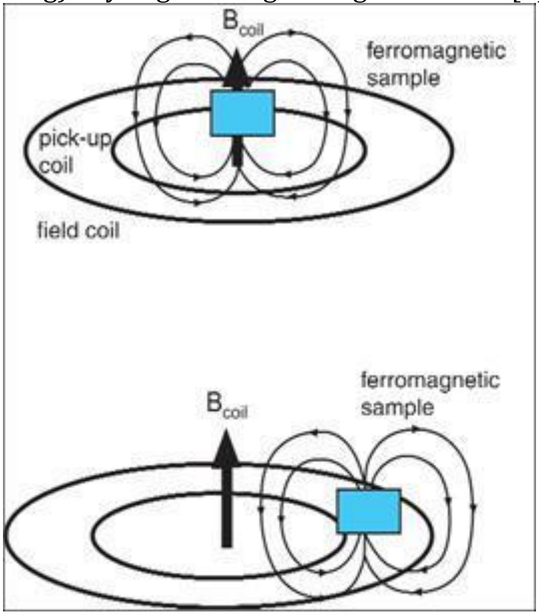

Figure 2. Example of pulse induction coil winding and their emf

2.3 Radio Transmitter and Receiver

The heart of wireless communication is radio transmitter and receiver, it has many uses and application in the present while also compactly made, thus can be integrated into mobile devices. The smallest form of the device was constructed from carbon nanotube at the size of only 400nm [5]. The base concept of this device is radio frequency from the oscillator, the oscillator carried out signal to antenna and further broadcast (transmitter). Then the broadcasted signal will be then receive (receiver). The receive signal will be modulate into the oscillator at original form.

The ranges of radio frequencies were ranging from 3Hz to 300GHz and comprised of information signal, modulator and oscillator [6]. Then their frequency for each usage is different where 30Hz-300kHz were use in AM radio while 3Hz-300GHz in wireless network and door opener [6]. Not just that the type of device also varies to usage, specification and simplicity, as an example at present for better portability and easy to use the transceivers were constructed (combination of transmitter and receiver). This device were actually as much the same as the conventional one but it combine of both functionality causing less effort in finding the receiving and transmitting device by being both of them. It only requires different programming to perform each of the ability.

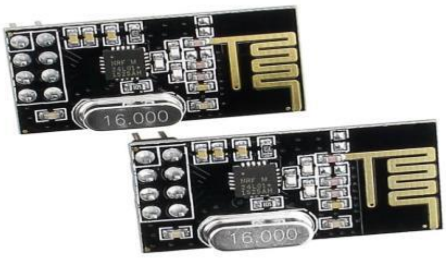

Figure 3. Transceiver with PCB mounted antenna

2.4 Microcontroller

Microcontroller is a small low cost computer on chips which usually consist of an 8 or 16 bit microprocessor (CPU), a small amount of RAM and volatile memory space, serial I/O timer and signal generator. This microcontroller often used to control one or more task in the operation of a system by using embedded code. Not just that it is frequently called embedded controller because microcontroller and support circuit are often build into or embedded in device controlled [8].

Usually the devices that utilize the use of microcontroller were electronic devices that require certain task to do simultaneously and automatically as the input were given. [8-13] The microcontroller usually operate at low power (0.5-1W) since the device they controlled are battery operated. PIC16F877A is the microcontroller that being use in this project, it can support lot of I/O port and can be easily integrated with the circuit [13]. This PIC microcontroller was able to mimic the sophisticated logic and electronic circuit based on their math logic and function.

Figure 4. PIC microcontroller kit

2.5 Actuator

One of the key components in robotic system is actuator. A robot requirement is degree of freedom where each of the movement requires an actuator to move to desired motion. Actuator can be classified into several types, hydraulic, pneumatic, electric, thermal or magnetic and mechanical. From all the class mention the most suitable for robot vehicles is electric actuator [9].

Servo motor is the combination of DC motor, motor driver and several gear. Gear is needed to increase the torque of the motor while maximizing the capability of motor. Next the motor driver is needed to interact with microcontroller to control the speed (PWM modulation) and direction (H-bridge circuit). Then the DC motor is the main part where it is needed to drive the servo system. It consists of stator, rotor and commutation mechanism. The stator has permanent magnet to create magnetic field in air gap between the rotor and stator, while the rotor has copper winding to allow the movement of current. The winding is altering the movement and polarity of current flow when the brush commutation delivered the current, this will allow the rotor to move continuously [9].

Figure 5. Servo motor with metal gear

2.6 Locomotion Mechanism

The locomotion mechanism is important in mobile robot to ensure it can move on variety of terrain based on their needs and costing. The wheel has several basic type, standard wheel, castor wheel, Swedish wheel and ball or spherical wheel. Based on the arrangement of wheel the robot can perform on variety of surface. The one used in this project is the track wheel or caterpillar wheel as shown in Figure 6. This wheel is very dependable in variety of terrain because it has better maneuverability in rough terrain and has higher friction in turns.

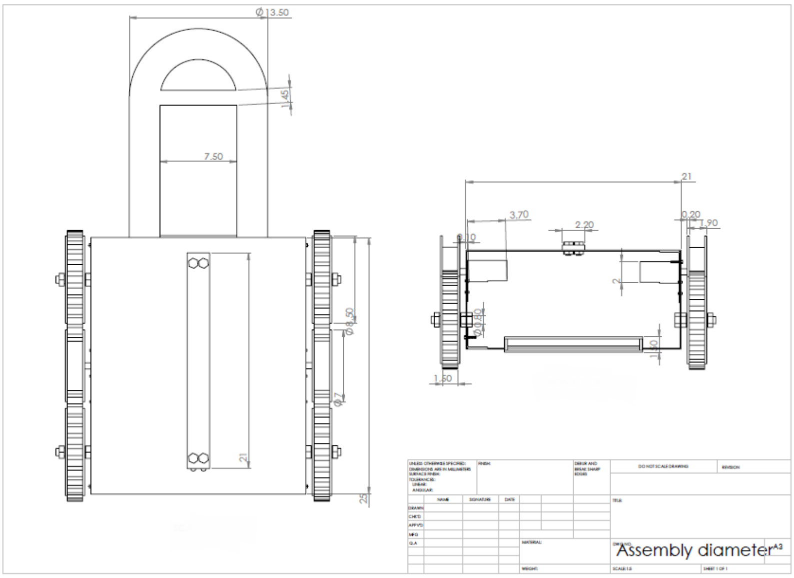

Figure 6. Caterpillar wheel robot

2.7 KNN Classifier

In this research work, KNN classifier was employed which is fast easy and accurate suggest by [13]. Each test metal frequency need to be predicted, the Euclidean distance Eq. (1) are used as the distance metric which applicable only to continuous variables. The accuracy of KNN classification will improved significantly if specialized algorithms are learned to distance metric. Examples of the specialized algorithms are Neighborhood Components Analysis and/or Large Margin Nearest Neighbor. A Euclidean Distance (Eq. (1)) is used to calculate how near the member of the training sample of the training set are to the examined test class. Euclidean Distance Measuring:

$$d_E(x, y) = \sum_{i=1}^{N} \sqrt{x_i^2 - y_i^2} \tag{1}$$

where *d* is the distance, *x* is the coordinate of x value, *y* is the coordinate of y value, and *N* is the number of features. A drawback to this majority voting type of classification appears when the more frequent examples class tends to influence the new vector prediction since they often came up in the *k* nearest neighbors especially when it computed the neighbors due to the large number that they have. In order to overcome this drawback, the classification weight takes into account the test points distance to its *k* nearest neighbors. [13] suggest that in binary classification problems (two class), *k* is chosen as an odd number in order to avoids tied. This method is called the bootstrap method.

3. RESULTS AND DISCUSSION

Table 1 The Cumulative Results from all Samples

Type of Metal	Channel 1				Channel 2			
	Frequency (Hz)	Peak to peak(V)	Accuracy %	Sensitivity %	Frequency (Hz)	Peak to peak(V)	Accuracy %	Sensitivity %
Initial	7.861k	904.90m	90.23	90.11	89.15k	594.70m	91.43	91.00
Nickel-Brass	7.851k	908.40m	91.24	90.56	89.28k	593.30m	92.64	91.11
Copper-Nickel	7.859k	921.60m	92.22	91.10	89.12k	600.60m	93.12	91.22
Aluminium Alloy	7.921k	905.10m	93.00	91.12	89.25k	589.40m	94.00	91.00
Aluminium	7.854k	908.40m	90.35	90.11	89.22k	585.30m	91.05	90.00
Brass	7.891k	903.00m	91.09	90.09	89.26k	588.00m	92.13	91.12
Iron	7.839k	921.70m	92.06	91.06	89.21k	597.30m	93.21	91.87
Low Carbon Steel	7.844k	906.70m	90.91	90.11	89.17k	589.50m	91.43	91.33

From the summarize value in Table 1, the initial value has been obtained during the first test to show the different when metal is detected. The initial value to detect copper is a bit different because the material use in coil is also copper. The frequency of coil oscillate were almost matching with the copper sample, so to detect copper is a bit tricky than other metal. From the result, to detect copper the initial frequency must be calibrated to higher values than others (channel 2).

The data show varies frequency for each metal at channel 1. The table indicator show that two metal (aluminum alloy and brass) is emitting higher frequency than the other at low frequency calibration (search coil). Beside two metal mentions, the other is only emitting a small frequency. Then at channel 2 the reference coil that is manually calibrated by hand shows almost the same frequency for each metal except the copper. Finally all the results prove that KNN can classify each of metal accurately and sensitively with percentage higher than 90%.

4. CONCLUSION

In conclusion all the objective of these Metal detector project was achieve successfully and reliable to detect variety of metal with simple calibration for each metal. The successful of data obtain is proving this metal detector is able to detect variety of metal via KNN. Then lastly this product also can move on variety of terrain surface with only small problem that could be solve with simple adjustment.

ACKNOWLEDGEMENTS

The support from University Malaysia Perlis UniMAP for facilities and laboratories, supervisor, co-supervisor, parents and friends is acknowledged.

REFERENCES

[1] Carl V. Nelson, Metal Detection and Classification Technologies, Johns Hopkins APL Technical Digest, (2004), Volume 25, number 1.
[2] Garrett, C. L. Modern Metal Detectors, RAM Publishing, (2002).
[3] Kasper Jensen, Rene Jensen, Michael Nielsen, (Title: Metal Detector, 1 December 2003). https://bodhi3.files.wordpress.com/2013/05/metaldetector.pdf [4] How to make metal detector, http://www.easytreasure.co.uk/bfo.htm [15/05/2016: 12.15am]
[4] P. Patel, "Technology Review: The World's Smallest Radio," (November 2007), [Online]. Available: http://www.technologyreview.com/Nanotech/19666/?a=f.

[5] Brekelmans and Johannes Hubertus Antonius, "LC Oscillator,", (Aug. 8, 2003) U.S Patent 7,176,766,.
[6] https://www.wpi.edu/Pubs/ETD/Available/etd 042811095908/unrestricted/alley.pdf
[7] Mcgraw-Hill, PIC Robotics-A Beginner‟s Guide to Robotics Project using PICmicro,(2004).
[8] Goris, K, Autonomous Mobile Robot Mechanical Design, Thesis, Vrije University Brussel, (2005), pp.11-27.
[9] Petit, F. Dietrich, A. and Alin Albu-Schäffer."Generalizing Torque Control Concepts: Using Well-Established Torque Control Methods on Variable Stiffness Robots", IEEE Robotics & Automation Magazine (RAM), (2015) , vol. 22, no. 4,pp. 37-51.
[10] Maurya, S. Dagar, A. and Sharma, L. "International Journal of Multidisciplinary Research and Development: Autonomous wheeled Robot Control in a coordinate system using Wireless Transmission", (2015), 2(3): 206-212,
[11] J.A. McNeil"The Metal Detector and Faraday‟s Law", Colorado School of Mines, Golden, CO, (2004), Vol. 42,
[12] Hall, P., Park, B.U., and Samworth, R.J. Choice of neighbour order in nearest- neighbour classification, *Annals of Statistics* 36 (5): (2008). pp. 2135-2152.
[13] Bermejo, S. Cabestany, J. Adaptive soft k-nearest-neighbour classifiers. Pattern Recognition, Vol. 33, (2000) pp. 1999-2005.