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Metal Detector via KNN for Vehicle Robot

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ABSTRACT

Through decades of use, several problems occur in the conventional metal detector where it becomes a burden when it is being carried for a long time, the price is so expensive and the user was exposed to the threat when using it at the dangerous site. In order to solve the problem, this research aims to develop a metal detector that is lighter, cheap and can be mobilized using a remote control. The frequency of different metal was classified via KNN Classifier where the obtained accuracy and sensitivity are higher than 90%.

Keywords: Autonomous, KNN Classifier, Metal Detection, Multi-Terrain, Microcontroller, Wireless Controller.

1. INTRODUCTION

By definition, a metal detector is a device that is used to detect varieties of different type of metal. The metal detector device can be classified into four types which are security, hobby, industrial and marine search, and recovery type. The type of metal detector that is widely used is the security type where it can be seen in airports and places that have a 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 louder. The longest range of metal detection is from hobby type where it can detect almost 3 metres away [2]. The device is portable and required onsite operation.

2. MATERIAL AND METHODS

2.1 Model and Data

Circuit of a metal detector varies depending on the usage and material use. Among the popular type of metal detector device that is commonly used are the Beat Frequency Oscillation (BFO) metal detector, Pulse Induction (PI) detector, and Very Low Frequency (VLF) detectors. BFO works based on the change of frequency when the coil detector oscillates. Next, the detected frequency was then matched with reference oscillator where the oscillation frequency was produced by the circuit system [3].

BFO type metal detector circuit is easy to make and only requires cheap material and component. In addition, the circuit does not require the Integrated Circuit (IC) that is hard and expensive to obtain locally. Moreover, the ranging of the detection can be easily manipulated by varying coil A (search loop) turns, while 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 and resistor also a few others. In Figure 1, the right portion of the circuit is

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used to control the audio output of the speaker while the left side contains important parts for metal detection [4].

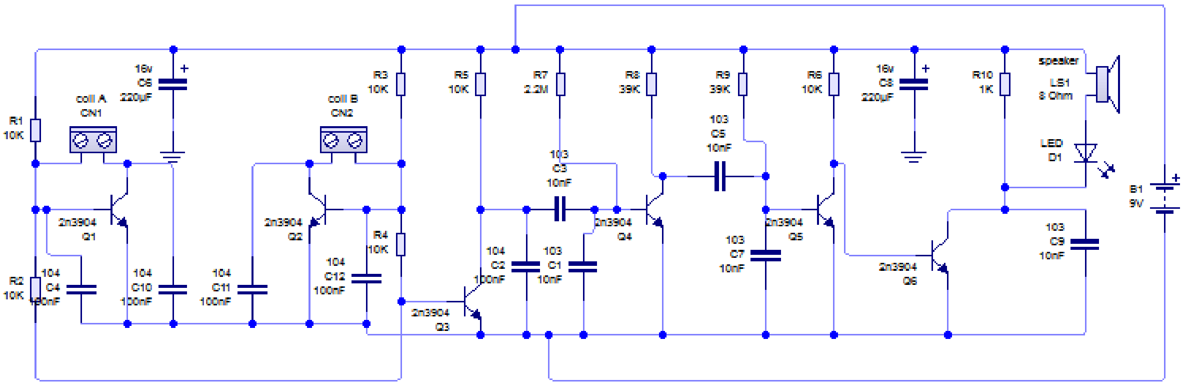

Figure 1. BFO metal detector circuit.

The next type of popular metal detector is The Pulse Induction (PI) detector. It is different than the BFO metal detector where it sends a short magnetic pulse and then producing spark in a coil (reflected pulse). The field shape of the reflected pulse changes when the detector getting closer to the metal object, thus causing a disturbance and amplification to the pulse. Then, the output is converted into a sound or light signal by the circuit [5-10]. This type of metal is being used by the previous researcher where the detector used a single-coil type PI detector named "Pulse One Metal Detector". The circuit used was provided in the G.L Chemelec website and utilised the IC 555 [11]. The pulse generated is continuous 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, a transistor served as a switch to change the mode of the detector between producing signals to listening for signals. The detection system enhances any distinguished signal 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 coil is creating signals. This alarms the administrator of the presence of any metal objects. Batteries are utilized as the power source and other incorporated circuits to ensure that a sustainable voltage is supplied even when the batteries are gradually depleted down to a specific point [11].

Very Low Frequency (VLF) is another type of metal detector device that operates 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 used in this project is the BFO detectors it is cheap and easy to find components. Furthermore, it is also reliable for the detection of metals in underground.

2.2 Induction Coil

The coil used in the BFO metal detector used pulse induction concept where two coils were involved. The first coil shown in Figure 2 is used for searching (also 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 for metal detection. By adjusting the oscillators in order for both coils to have nearly the same frequency, the difference between coils made an audible beat sound, where a slight change of sound will be heard when it is closed to a piece of metal. Based on the literature review, it has been found that the best practice is to set the search oscillator fixed at 100khz while the reference oscillator is set to be adjustable 100 kHz plus or minus 250 Hz. This gives a beat note of 250 Hz to 0 to 250 Hz. 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 5 Hz (motor boating) any slight change being noticeable [4].

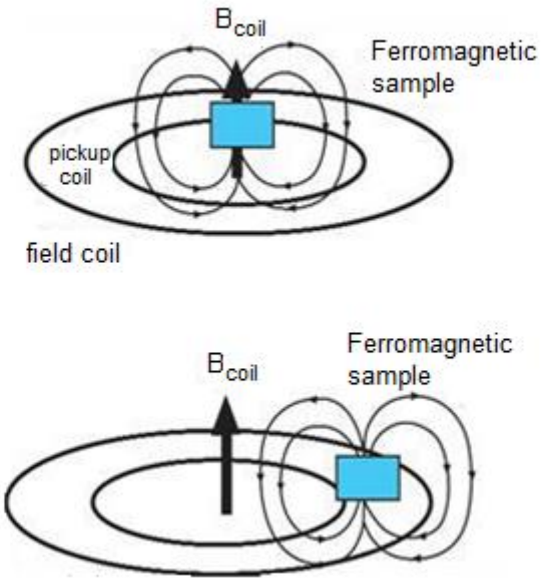

Figure 2. Example of pulse induction coil winding and their emf.

2.3 Radio Transmitter and Receiver

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

The ranges of radio frequencies ranging from 3 Hz to 300 GHz and comprised of the information signal, modulator and oscillator [6]. The frequency for each user is different where 30 Hz-300 kHz is used in AM radio while 3 Hz-300 GHz is used by the wireless network, mouse and keyboard, and door opener [6]. Apart from that, the type of device also varies in terms of usage, specification and simplicity. As for example, at present for better portability and easy to use, the transceivers were constructed (a combination of transmitter and receiver). Transceiver actually has the same capability as the conventional transmitter and receiver. However, instead of two separate modules (transmitter and receiver), the transmitter and receiver is combined into one module but having both functionalities and the module is called a transceiver. Hence, save the developer time and effort in finding the individuals receiving and transmitting modules because a transceiver already has both functionalities. The transceiver only requires different programming/ instruction to perform each operation (transmit or receive). Figure 2 shows a transceiver with PCB mounted antenna. The transceiver in Figure 3 operate based on IEEE802.11 standard or commonly known as WiFi.

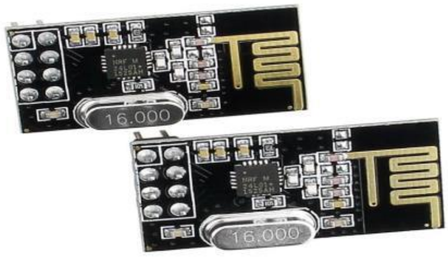

Figure 3. Transceiver with PCB mounted antenna.

2.4 Microcontroller

A microcontroller is a small, low-cost computer on chips which usually consist of an 8-bit 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. Besides that, it is frequently called an embedded controller because the microcontroller and support circuit is often built into or embedded in device controlled [8].

Usually, the devices that use microcontroller were electronic devices that require a certain task that needs to be performed simultaneously and automatically as the input was given [8-13]. The microcontroller usually operates at low power (0.5-1 W) since the device they controlled is battery operated. PIC16F877A is a microcontroller used in this project where it can support a lot of I/O port and can be easily integrated with a suitable circuit design [13]. Figure 4 shows the PIC16F877A attached to a programmer. This PIC microcontroller was able to mimic the sophisticated logic and electronic circuit based on mathematical logic and function.

Figure 4. PIC microcontroller kit.

2.5 Actuator

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

Servo motor is the combination of DC motor, motor driver and several gears. The example of servo motor with gear is shown in Figure 5. Gear is needed to increase the torque of the motor while maximizing the capability of a 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 in order to drive the servo system. The DC motor consists of stator, rotor and commutation mechanism. The stator has a permanent magnet to create a magnetic field in the 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 allowing 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 a variety of terrain based on their needs and costing. The wheel has several basic types which are the standard wheel, castor wheel, Swedish wheel, and ball or spherical wheel. Based on the arrangement of the wheel, the robot can perform on a variety of surface. The one used in this project is the trackwheel or caterpillar wheel as shown in Figure 6. This wheel is very reliable in a variety of terrain because it has better manoeuvrability in rough terrain and has higher friction in turns.

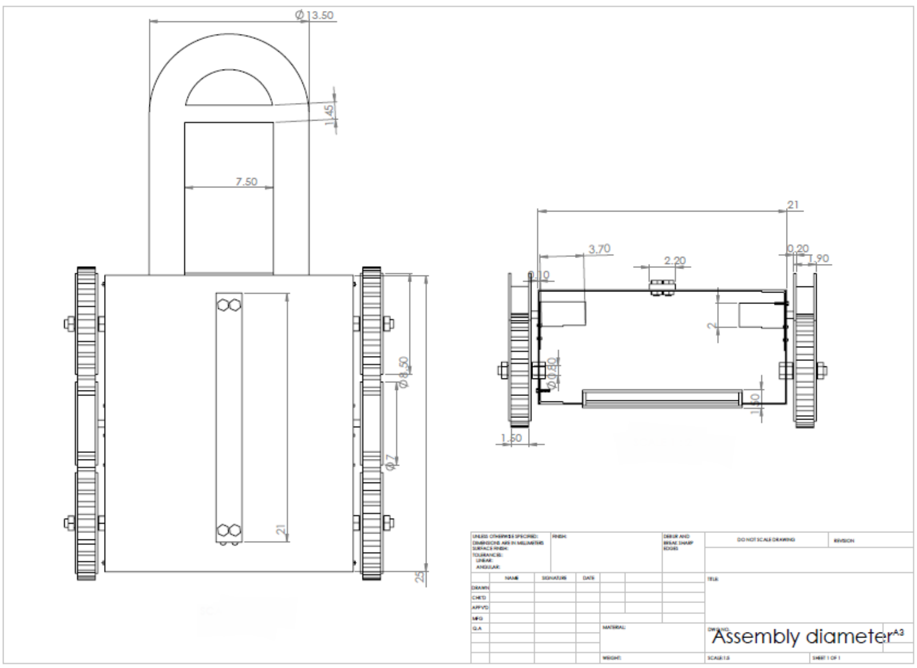

Figure 6. Caterpillar wheel robot.

2.7 KNN Classifier

In this research work, K-Nearest Neighbour (KNN) classifier was employed which is fast, easy and accurate classification technique as suggested by [13]. Each test metal frequency needs to be predicted, hence, the Euclidean distance Eq. (1) are used as the distance metric which only applicable to continuous variables. The accuracy of KNN classification can be 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.

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

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 neighbours especially when it computed the neighbours 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 neighbours. [13] suggest that in binary classification problems (two-class), k is chosen as an odd number in order to avoid 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 summarized value in Table 1, the initial value has been obtained during the first test to show the difference when metal is detected. The initial value to detect copper is a bit different because the material used in the coil is also copper. The frequency of coil oscillates was 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 in Table 1 show different frequency for each metal in channel 1. The table indicates that two metal (aluminium alloy and brass) is emitting higher frequency than the other at low-frequency calibration (search coil). Besides the two metal mentioned, the other metals are 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 a percentage higher than 90%.

4. CONCLUSION

In conclusion, all the objective of this metal detector project was successfully achieved and able to detect a variety of metal reliably with simple calibration for each metal. The success of the data obtained proved that this metal detector is able to detect a variety of metal via KNN. Lastly, this product also can move on a variety of terrain surface with a small problem that could be solved with a simple adjustment.

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