Earthquake Early Warning System Real Time Design Using Total Electron Content and Geomagnetism with Fuzzy Logic

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Abstract

Design of an earthquake early warning is using data real time of geomagnetism from fluxgate magnetometer sensor and Total Electron Content (TEC) in ionosphere layer that measured by transmitter and receiver FM wave. Both of those types are processed by fuzzy logic as a determinant result of measure. The result is inferred as an information such as an earthquake prediction strength that will happen, and also time and epicenter location. This information is delivered by Short Message Service (SMS) in telephone number that has been registered.
Keywords: *Earthquake, geomagnetism, TEC, Fuzzy*

1. Introduction

Natural disaster that occurred in Indonesia especially for earthquake get many victims and materials. An earthquake in Aceh, Medan, Padang, Jogjakarta and also the others should give motivate to the researcher for more focus on research about an earthquake especially for design of an earthquake early warning. An earthquake is a natural disaster, where the earthquakes that occurs is one of earth characteristic to defending its stability with another word natural disaster is sure happen. The problem is we cannot prediction the time when natural disaster is coming, the strength and location of the earthquake it self. So that it is needed to build an early warning system with real time. The purpose of this research to predict the time, strength and location so finally we can prepare all the things to face that natural disaster. The basic of built this system is to knowing the sign or early indication physical earth phenomenon when the earthquake is happening. Some signs or early indication for the earthquake is Total Electron Content phenomenon in the ionosphere layer[8],[6],[2]. Because of plate movement influence the gravity and magnetic minerals in the earth so in disturb stability of the electromagnetic field force. This disturbance can reach the radius until 400 KM in the top of earth surface. In the ionosphere layer and geomagnetism improvement in the earth surface of the certain time before the earthquake is coming [4], [3] and the geomagnetism can be censored by using fluxgate magnetometer sensor [1]. So that the purpose of this research is to build the earthquake early warning system with hardware and software form and will produce the information of earthquake early warning such as time, location, and the strength of the earthquake itself and this information will be delivered by using Short Message Service (SMS).

2. Methods

The method used in this research is began from fluxgate magnetometer sensor system design and FM receiver (system A) and system application design using fuzzy logic in the PC (system B). So this is the design of the system2.1 Subheadings

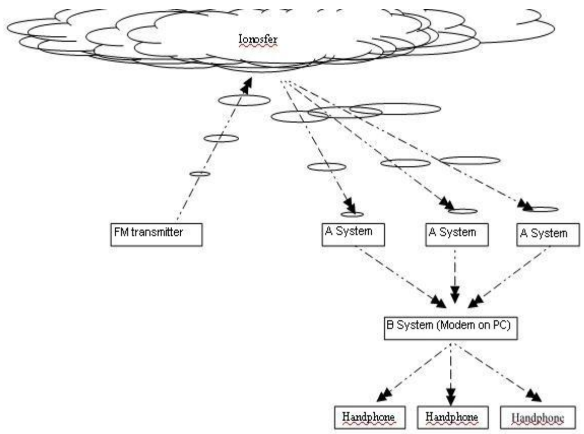

Fig. 1 Overall system design

2.1 The design of fluxgate magnetometer sensor and FM receiver (system A)

Fluxgate magnetometer sensor is used FLC 100 has range of 100 μT, the output voltage of ± 1 V / 50 μT, the output pin sensor to analog input pin (A0) Arduino Uno microcontroller. FM receiver IC that used is LA1260, RF signal (Radio Frequency) on pin 6 entry to the signal transistor FCS9018. The output voltage conditional signal is entered into the ADC analog input pin (A1) ArduinoUno. Data resulting from the conversion range of 0 to 1024, 10-bit ADC. And then these data transmitted using wavecom modem Q2406B every 30 minutes to the modem runs on a computer. To improve the accuracy of estimates of earthquake system A needs to be propagated. Here's fluxgate sensor design magnetometer and FM receiver and modem wavecom Q2406B.

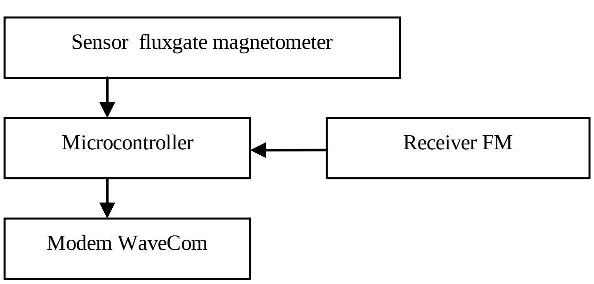

Fig. 2 Sensor fluxgate magnetometer and an FM receiver (System A) design

After that design of software system on the microcontroller Arduino Uno. This is software design for fluxgate magnetometer sensor control and RF receiver FM on Arduino Uno microcontroller.

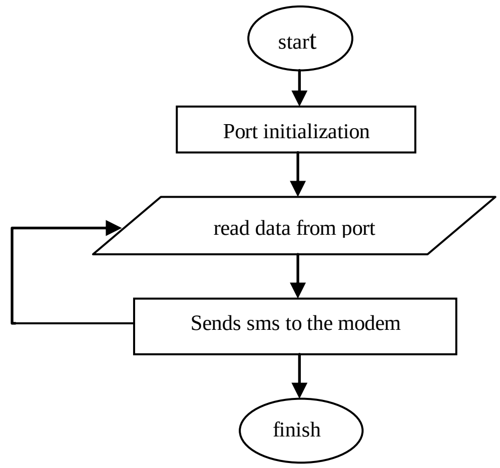

Fig. 3 Fluxgate magnetometer sensor and FM receiver software design

2.2 Application system Design (system B)

The data of geomagnetism from fluxgate magnetometer sensor and RF wave from FM receiver will be processed or analyzed by using fuzzy logic. Fuzzy logic is rule based technology that can representing the imprecision with creating the rule using subjective value or approximate value. Fuzzy logic can explain the phenomenon or certain process linguistically, than representing in flexible small number of rules. The organization use fuzzy logic to create the software system that can get knowledge contain of linguistic ambiguity [7],[5] When data earned is earthquake data potential so fuzzy logic can determine or predict the time, strength and location of the earthquake. This is the design of the system (system B).

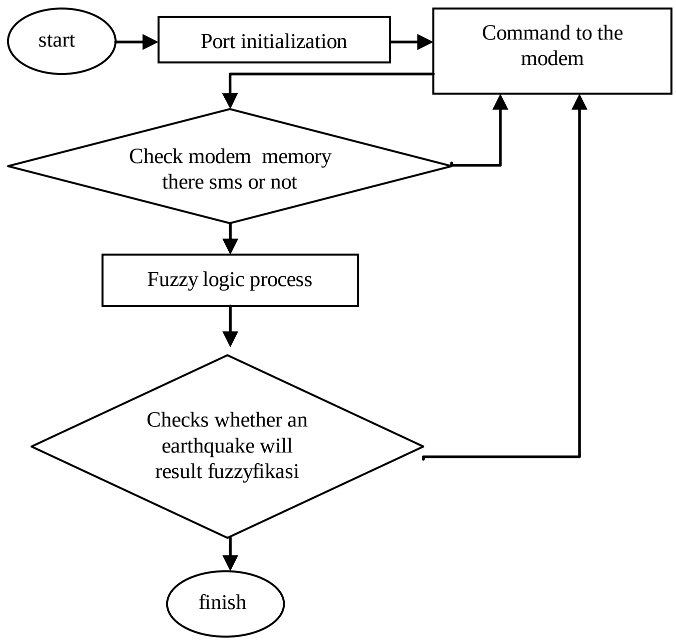

Fig. 4 Flow chart of system B

This table describes the RF voltage converse table (Radio Frequency) which will be used to determine the Total Electron Content.

Table 1 RF Voltage table converse

No	RF voltage converting value (decimal)	Grade (fuzzy set)
1	70	Low
2	85	Medium
3	100	High

These values are obtained by the following formula:

$$Decimal\ Value = \frac{Vin}{5} x1024$$

where:

Vin : voltage value is entered into the microcontroller

5 : maximum voltage for microcontroller analog input

1024 : number of combinations of data for existing 10-bit ADC on the microcontroller (2^{10}).

Range fluxgate earth magnetic has range from 25 till 65 µT and with reference to the data sheets sensor FLC 100 where the value of the output voltage of • 1 V / 50 µT so we can determine the value of a variable to the value of the sensor voltage conversion as follows.

(1) For a value of 25 µTflux magnet

$$\frac{1}{x} = \frac{50}{25}$$

$$x = 0{,}5$$

Voltage of 0.5 volts conversion on ADC ArduinoUno as follows:

$$DecimalValue = \frac{0.5}{5} x1024$$

$$Decimal\ Value = 102{,}4$$

(2) For the value of 45 µT fluxgate

$$\frac{1}{x} = \frac{50}{45}$$

Voltage of 0.9 volts conversion on ADC ArduinoUno as follows:

$$Vout = Vin\ x \frac{R1}{R1+R2}$$

$$Decimal\ Value = 184{,}32$$

(3) For value of 65 µTflux magnet

$$\frac{1}{x} = \frac{50}{65}$$

$$x = 1{,}3$$

Voltage of 1.3 volts conversion on ADC ArduinoUno as follows:

$$Decimal\ Value = \frac{1{,}3}{5} x1024$$

$$Decimal\ Value = 266{,}34$$

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Table 2 Voltage conversion value table fluxgate magnetometer sensor

No	Sensor voltage conversion value	Grade (fuzzy set)
1	102.4	Low
2	184.32	Medium
3	266.24	High

3. Result and Discussion

3.1 The Result of Fluxgate Magnetometer Sensor

To test the sensor design in microcontroller needs replace the sensor with the potentiometer. Potentiometer is assembled into a voltage divider circuit. Changes the value of the voltage in the voltage divider circuit will has the same value in the change of geomagnetism value. This case is done to make easy in the test of system without should waiting for geomagnetism value changing.

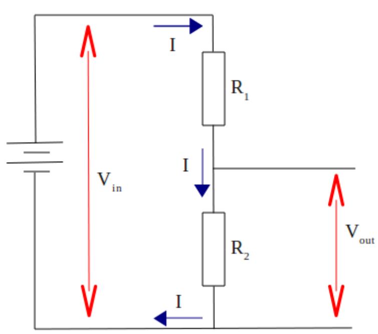

Fig. 5 Voltage divider circuit

Following to formula

$$Vout = Vinx \frac{R1}{R1 + R2}$$

Vout : potentiometer output voltage (volts)
Vin : 5 Volts (volts)
R1 and R1: potentiometer resistance value (ohms)
By using the ADC conversion formula

$$Decimal\ Value = \frac{Vin}{5} x1024$$

Vin: Vout of the output voltage divider circuit potentiometer
From the above formula and using the value of resistance 10 KΩ pot meters and measurement data obtained by avoltage divider circuit output voltage as follows:

Table 3 Vout voltage divider circuit

R1 (ohm)	R2(ohm)	R1/(R1+R2)	Vin	Vout
1	9	0.1	5	0.5
2	8	0.2	5	1
3	7	0.3	5	1.5
4	6	0.4	5	2
5	5	0.5	5	2.5
6	4	0.6	5	3
7	3	0.7	5	3.5
8	2	0.8	5	4
9	1	0.9	5	4.5

After that Vout is converted into a data decimal ADC process results, the data conversion results as follows:

Table 4 The results of the ADC

Vin (Volt)	ADC Value
0.5	102.4
1	204.8
1.5	307.2
2	409.6
2.5	512
3	614.4
3.5	716.8
4	819.2
4.5	921.6

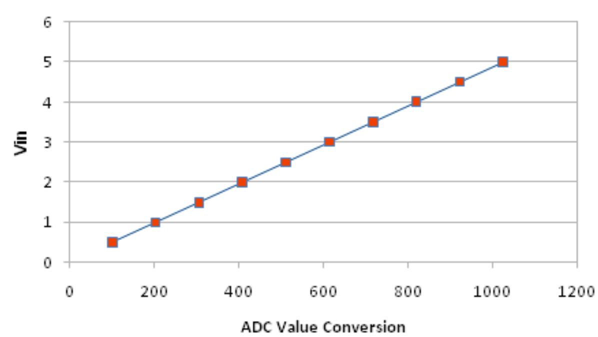

Fig. 6 Graphs the relationship between Vin and the decimal

Decimal value then sent to the modem to be processed along with the data of RF (Radio Frequency). The Results of Modem and FM Receiver Design. The FM Receiver is used to determine the Total Electron Content, the voltage coming out of the IC LA1260 pin 6 is a representation of the RF power (Radio Frequency). Pin 6 of IC LA 1260 amplifier circuit coupled to the ADC before entering into the microcontroller.

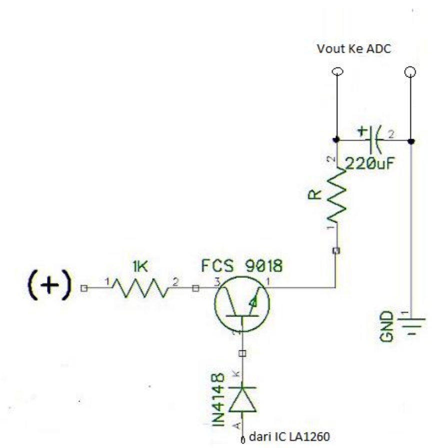

Fig.7 Amplifier circuit voltage

The size of the circuit Vout depends on the size of the RF. It can be used as a representation of Total Electron Content in the ionosphere if the radio waves fired into the ionosphere, radio waves are partially reflected by the ionosphere. To perform system testing can be done by placing the radio waves at a specific frequency point (87 MHz), then measurethe voltage output of the amplifier circuit and see the results of the ADC. This is done repeatedly by changing thetransmitter frequency point or FM receiver. Changes in the frequency point represents Total Electron Content on ionosphere layer. With 87 MHz frequency point FM receiver and make changes to the FM transmitter frequency point and then measure the output voltage of the amplifier circuit and see the results of ADCdata measurement converse.

Table 5 Measurement of FM receiver

Frequency Point receiver 87 MHz	Changes in the frequency of the transmitter point	Vout (volt)	ADC conversion
87	85.8	0.1	20.48
87	85.9	0.2	40.96
87	86	0.3	61.44
87	86.1	0.4	81.92
87	86.2	0.5	102.4
87	86.3	0.6	122.88
87	86.4	0.7	143.36
87	86.5	0.8	163.84
87	86.6	0.9	184.32
87	86.7	1	204.8
87	86.8	1.1	225.28
87	86.9	1.2	245.76
87	87	1.3	266.24
87	87.1	1.2	245.76
87	87.2	1.1	225.28
87	87.3	1	204.8
87	87.4	0.9	184.32
87	87.5	0.8	163.84
87	87.6	0.7	143.36
87	87.7	0.6	122.88
87	87.8	0.5	102.4
87	87.9	0.4	81.92
87	88	0.3	61.44

From the table above the graph obtained the relationship between changes in the frequency of the ADC conversion point.

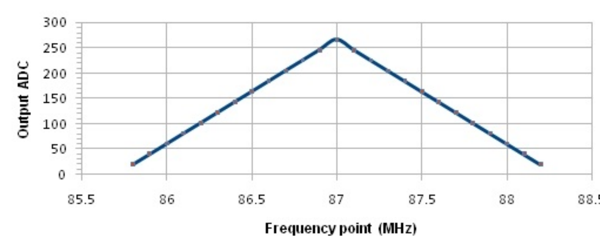

Fig. 8 Frequency point change

By connecting data from table 4, table 5 and table 6 and processed using fuzzy logic will be obtained strength or magnitude earthquake quake description.

Table 6 Earthquake quake description with Fuzzy Association

Magnitude	Description	Fuzzy Association
Under 2.0	Micro	Low
2.0 – 2.9	Minor	
3.0 – 3.9		
4.0 – 4.9	lightweight	Medium
5.0 – 5.9	Medium	
6.0 – 6.9	Strong	High
7.0 – 7.9	Major	
8.0 – 8.9	Great	
9.0 – 9.9		

With fuzzy rules for RF (Radio Frequency) as follows

```
if RF < X0 then z1 := zone1(cv1);
if ((RF >= X0) and (RF < X1)) then z2 := zone2(cv2);
if ((RF >= X1) and (RF < X2)) then z3:= zone3(cv3);
if ((RF >= X2) and (RF < X3)) then z4:= zone4(cv4);
if  RF>= X3 then z5 := zone5(cv5);
```

and rules as follows fuzzy to geomagnetism

```
if magnet < T0 then y1 := zone6(cv6);
if ((magnet >= T0) and (magnet < T1)) then y2:= zone7(cv7);
if ((magnet >= T1) and (magnet < T2)) then y3:= zone8(cv8);
if ((magnet >= T2) and (magnet <=T3)) then y4:= zone9(cv9);
if magnet >= T3 then y5 := zone10(cv10);
```

Then process as follows fuzzy logic

```
g1 := m1 * (S0-S1) + S1;
g2 := m2 * (S1-S0) + S0;
g3 := m2 * (S2-S3) + S3;
g4 := m3 * (S1-S0) + S0;
g5 := m3 * (S2-S3) + S3;
g6 := m4 * (S1-S0) + S0;
g7 := m4 * (S2-S3) + S3;
g8 := m5 * (S3-S2) + S2;
g9 := m6 * (S3-S2) + S2;
g10 := m7 * (S1-S0) + S0;
g11 := m7 * (S2-S3) + S3;
g12 := m8 * (S3-S2) + S2;
g13 := m9 * (S3-S2) + S2;
n:=
((m1*g1)+(m2*g2)+(m2*g3)+(m3*g4)+(m3*g5)+(m4*g6)
+(m4*g7)+(m5*g8)+(m6*g9)+(m7*g10)+(m7*g11)+(m8*
g12)+(m9*g13))/(m1+(m2*2)+(m3*2)+(m4*2)+m5+m6+(
m7*2)+m8+m9);
```

n: magnitude earthquake value
as well as rules for magnitude fuzzy specification following earthquake

```
ifgempa< S0 then w1:= zone11(cv11);
if ((gempa>=S0) and (gempa<S1)) then w2:=zone12(cv12);
if ((gempa>=S1) and (gempa<S2)) then w3:=zone13(cv13);
if ((gempa>=S2) and (gempa<=S3)) then w4:= zone14(cv14);
ifgempa>= S3 then w5:=zone15(cv15);
```

n: value magnitut earthquake
as well as rules for magnitut
spesifiaksi fazzy following earthquake

Tabel 7. Fuzzy sets RF

RF value	Result of fuzzy sets	Membership value
70	Low	0.5
70	Low	0.5
70	Low	0.5
85	Medium	1
85	Medium	1
85	Medium	1
100	High	1
100	High	1
100	High	1

Table 8 Fuzzy sets geomagnetism

Geomagnetism value	Results of fuzzy sets	Membership value
102	0.6	Medium
184	1	Medium
266	1	High
102	0.6	Medium
184	1	Medium
266	1	high
102	0.6	Medium
184	1	Medium
266	1	medium

Table 9 Fuzzy sets value magnitude

Magnitude	Results of fuzzy sets	Membership value
5.46	Medium	1
6	Medium	1
6	Medium	1
6.58	Medium	0.8
9	High	1
9	High	1
6.58	Medium	0.8
9	High	1
9	High	1

The epicenter an earthquake can be estimated with where fluxgate magnetometer sensor location. By including the coordinates sensors and transmit data along with coordinates of data geomagnetism and RF will be able to determine the epicenter.

4. Conclusions

From the research can be concluded that early warning earthquake system can work well in the test with potentiometer functionalized to replace of fluxgate magnetometer sensor and the change of frequency point FM transmitter. This system determines the location and the strength of the earthquake but it is not able to determine when the earthquake happen, this case due to system A only consist of one system. To determine the time of the earthquake we need more than one system A.

Acknowledgments

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References

[1] AgfiantoEko Putra, Rosmalini Harahap, *PurwarupaPengukur Medan Magnet Berbasis Sensor Magnetik Fluxgate Dan Mikrokontroler Atmega8535*, Prodi. ElektronikadanInstrumentasi, JurusanFisika, FMIPA – UGM, Yogyakarta (in bahasa Indonesia)

[2]F. Li · M. Parrot, *Total Electron Content Variations Observed By A DORIS Station During The 2004 Sumatra–Andaman Earthquake*, Springer-Verlag 2006

[3]Jan Kozák And Axel Plešinger,*Beginnings Of Regular Seismic Service And Research In The Austro-Hungarian Monarchy: Part I*, Geophysical Institute, Academy of Sciences of the Czech Republic, Boční II/1401, 141 31 Prague 4, Czech Republic (kozak@ig.cas.cz, pless@ig.cas.cz), 2002

[4]Kanata B, dkk, *PengukuranResistivitasPada Daerah Dugaan Sumber Penyebab Anomali Geomagnetik Di Pulau Lombok NTB* Jurnal Teknik Elektro, Vol. 128 No. 1 Januari - Juni 2009 (in bahasa Indonesia)

[5]Laudon, Kenneth C; dan Laudon, Jane P. 2008. Sistem Informasi Manajemen. Salemba Empat: Jakarta (in bahasa Indonesia)

[6]Santosh Kumar Jain, Gopal Panda and S K Vijay, *Study Of Variation In Slab Thickness Of Ionospheric F-Region During Earthquake By Wavelet Analysis*, Indian J. Phys. 84 (4), 359-365 (2010)

[7]Sri Kusumadewi, HariPurnomo, 2010, AplikasiLogika Fuzzy untuk Pendukung KeputusanEdisi 2**,** GrahaIlmu, Jakarta (in Bahasa Indonesia)

[8]Y. Fukumoto, M. Hayakawa, H. Yasuda, 2001, *Investigation of Over-Horizon VHF Radio Signals Associated with Earthquakes*, European Geophysical Society.

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