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ERROR DATA ANALYZING OF THE INTEGRATION OF THE SENSORS WITH DIFFERENT MEASURING BOUNDARIES IN DYNAMIC ENVIRONMENTS

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ABSTRACT

Data accuracy is important to determine a target. Mobile robots are used in dynamic environments. At dynamic environments, the noise factor and situation of objects are changeable. A sensor may not work properly in dynamic environmenst. The noise factor affects getting accurate data negatively. These factors depend on sensor types. Therefore, one of the goals of sensor integration i, to quench one or more sensor disadvantages by using other sensor or sensors, get more accurate and reliable data, reduce noise factor, determine and analyze more options of target or targets.

Every sensor has a measurement range and this range changes according to the sensor types. The sensor has two boundaries; lower boundary and upper boundary. It is usually zero below the lower boundary. Above the upper boundary it keeps the maximum output value and Is usually stable. Essentially, the sensor data over the range called error data. If the value to be measured in an integration composed of the sensors is out of ranges of some sensors, the data of these sensors is to be eliminated. Eliminated data are bad data. Error data analyzing methods are used to determine bad data. Chauvenet's criterion is one of these methods. A new model eliminating the sensor data is developed. The logic equations are used in Chauvenet's criterion in this model to determine the data is over range or not. The logic equations are used in Chauvenet's criterion in this model to determine if the data is over range or not.

Keywords: *Dynamic environment, Chauvenet's criterion, Sensor integration, Measuring Boundaries*

1. INTRODUCTION

The aim of sensor integration to determine and analyze a target is to get more accurate data or to determine and analyze more targets. Lots of methods are developed for integration [1, 2, 3]. Dempster-Shafer Evidence Method, Bayesian Formula [2] is a method to integrate different sensors. Fuzzy ARTMAP is used for sensor integration on mobile robots [4]. Separately Omni-directional Stereo and Laser Range Finder integration is used to make robot map [5].

Accuracy and reliability are important at measuring. A sensor has a lower boundary and upper boundary (such as `low cut-off frequency and high cut-off frequency` in frequency domain). Below the lower boundary is dead region and above the

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upper boundary is saturation region. It is zero below the lower boundary. Above the upper boundary it keeps the maximum output value.

In general, arithmetic mean, Gaussian distribution method, etc. data analysis methods are used to make a relation between two or more parameters. Chauvenet's Criterion and Peirce's criterion are methods that reject "bad" data as being statistically unlikely to have come from the true Gaussian population [6, 7, 8]. Some of these methods are used to obtain data from the sensor in different times. These data can be obtained by more sensors at a time. Synchronous measurement is more usual to eliminate noise factor.

Chauvenet criterion defines an acceptable scatter around the mean value. The ranges counted by $B=\overline{X}\pm\tau.\sigma$. $\overline{X}$ is the mean and σ is the standard deviation for N readings. τ is the Gaussian table value (not t-test) and the probability calculated by using 1-1/2N [6]. The data out of the range is bad data and must be rejected. The Chauvenet criterion cannot be used more than once [6, 7].

2. THE MEASURING REGIONS AND RELIABILITY OF THE INTEGRATION OF THE SENSORS

There are three main regions for a sensor to measure; below the lower boundary region, measuring region, upper boundary region. There are four basic regions for different types of sensors' integration.

- I. Region: The region of all sensors' lower boundaries below. In this region the measuring result is zero, as there is no measuring.
- II. Region: Common measuring region for all sensors. In this region all data are applied (computed)
- III. Region: Uncommon measuring region for sensors (not all). At the integrated sensors, which have common regions data are applied.
- IV. Region: The region of all sensors upper boundaries above. The result value is infinite.

Logic equations are used in this model for these regions. Actually this model is composed of Chauvenet criterion and logic terms. One or more sensors which are over the measuring region are eliminated and never interact the mean. And, it shows the infinite value for the region of all sensors' upper boundaries above. We need two outputs of a sensor to determine these regions in this model. The outputs are logic outputs. Not to confuse the decimal and logic terms, loja or luju terms is used instead of one character. The low limit of a sensor measuring is shown by loja and the high limit of a sensor measuring is shown by loju. The term loja is 0 below the low limit, and is 1 above the high limit. The model is shown below for A to N sensors;

A_i= The output value of i. sensor A
N= The number of sensors
loja= 0 (There is no measuring value below the lower boundary)
loja= 1 (There is a measuring value below the lower boundary)
loju= 0 (There is no measuring value above the upper boundary)
loju= 1 (There is a measuring value above the upper boundary)
$loja_{Ai}$= The logic output of lower boundary of sensor A_i
$loju_{Ai}$= The logic output of upper boundary of sensor A_i

The logic equations by using EXNOR Gate, AND Gate and NOT Gate to determine the data to eliminate or not. Arithmetic mean $\overline{X}$ is;

$$\overline{X}=\frac{\sum_{i=1}^{n}A_i.(loja_{A_i}\odot loju_{A_i})}{\sum_{i=1}^{n}(loja_{A_i}\odot loju_{A_i})},$$

and it is showed as $\overline{X}=\frac{W}{Y}$. So, $W=\sum_{i=1}^{n}A_i.(loja_{A_i}\odot loju_{A_i})$ and $Y=\sum_{i=1}^{n}(loja_{A_i}\odot loju_{A_i})$. A new terms added in numerator and denominator to impede 0/0 situation and define space region. So, $\overline{X}=\frac{W+X}{Y+Z}$. $X=\prod_{i=1}^{n}(\overline{loja_{A_i}}.loju_{A_i})$ and $Z=\prod_{i=1}^{n}(loja_{A_i}.\overline{loju_{A_i}})$. Equation Z=1 and X=0 in I. region. So D=0/1=0 in I. region. If not used to X and Z, the result is D=0/0. Equation X=1 and Z=0 in IV. Region to make space and it means the region is over measuring distance. In II. and III. region X and Z are equal to 0 and ineffective result. The arithmetic mean is;

$$\overline{X} = \frac{\sum_{i=1}^{n} A_i.(loja_{A_i} \odot loju_{A_i}) + \prod_{i=1}^{n}(\overline{loja_{A_i}}.loju_{A_i})}{\sum_{i=1}^{n}(loja_{A_i} \odot loju_{A_i}) + \prod_{i=1}^{n}(loja_{A_i}.\overline{loju_{A_i}})}$$

Obtained standart deviation is;

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}[(\frac{\sum_{i=1}^{N} A_i.(loja_{A_i} \odot loju_{A_i}) + \prod_{i=1}^{N}(\overline{loja_{A_i}}.loju_{A_i})}{\sum_{i=1}^{N}(loja_{A_i} \odot loju_{A_i}) + \prod_{i=1}^{N}(loja_{A_i}.\overline{loju_{A_i}})} - A_i)(loja_{A_i} \odot loju_{A_i})]^2}{\sum_{i=1}^{N}(loja_{A_i} \odot loju_{A_i})}}$$

To define the acceptable scatter around the mean value σ, $\overline{X}$ and τ are used in Chauvenet criterion. Five different type of sensors are used in an example.

Sensor label	Sensor type	Measuring distance	Sens outp value
A	UM18-11116 ultrasonic sensor	100-2000 mm	4-20 mA
B	UM30-12113 ultrasonic sensor	60-600 mm	0-20 mA
C	UM30-13113 ultrasonic sensor	200-2000 mm	4-20
D	UM30-14113 ultrasonic sensor	350-5000 mm	4-20 mA
E	DME3000-211 lazer sensor	100-8000 mm	0-100 mA

Take into different measuring boundaries of sensors, 9 different areas are obtained;

Region	Measuring distance	Usable sensors
Zero region	**0-60 mm**	**None**
I. Region	60-100 mm	Sensor B
II. Region	100-200 mm	Sensor A, B, and E
III. Region	200-350 mm	SensorA, B, C and E
IV. Region	350-600 mm	Sensor A, B, C, D and E
V. Region	600-2000 mm	Sensor A, C, D and E
VI. Region	2000-5000 mm	Sensor D and E
VII. Region	5000-8000 mm	Sensor E
VIII. Region	Over 8000 mm	None

The error% for the regions are shown in table above;

	Approximately min.-max. error%		
Region	**Arithmetic mean**	**Chauvenet's criterion**	**New model**
Zero region	Not usable	Not usable	0
I. Region	80.6	100	3
II. Region	41.2	41.2	2
III. Region	21.6	2	2
IV. Region	2	2	2

V. Region	3.3-16	2	2
VI. Region	15.4-42.18	2-42.18	2
VII. Region	42.21-57	42.21-57	2
VIII. Region	Over 56.2	Over 56.2	Infinite region

In zero region all the sensors output are not usable. In first region only sensor B is usable, the others are not, so arithmetic mean or Chauvenet's criterion are not usable, too. If any sensor meauserement is out of measuring boundaries, this sensor data makes makes deviation. In II. region three sensors data of five sensors data are usable, but Chauvenet's criterion can not determine error data of sensor C and sensor D. Because all sensors data are in the measuring boundaries in Gaussian distribution. In III. region Chauvenet's criterion eliminated sensor D's data. In IV. region, all sensors data are usable, so arithmetic mean method is usable, too. In V. region sensor B is over its measuring boundary. Its data is error data for Chauvenet's criterion and eliminated. In VI. region sensor B and C are over their measuring boundaries, but their data are not out of Gaussian distribution boundaries. So they are not called as error data. In VII. region only sensor E is usable, the others are in saturation region. In VIII. region all sensors are in saturation reigon. This region is called as space by the new model.

3. CONCLUSIONS

The different types of sensors must be used to determine a target in dynamic environments. The measuring bondaries of sensors will be different between each other. The logic outputs of sensors showing lower and upper boundaries is used with Chauvenet's criterion in this work. The logic outputs are placed on new types of sensors nowadays, such as DME2000 SICK sensor, but the logic outputs do not show very definitely the lower boundary. The logic outputs help not to write hundreds lines of software for each sensor. Gaussian distribution is used in Chauvenet's criterion, so it is more useful than arithmetical mean. In this paper, logic functions are added in Chauvenet's criterion and new model is developed. This model is used for many different types of sensors' integration in dynamic environments. The new model determines the infinite or space region and is very useful for a mobile robot.

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