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## THE EXPERT EVALUATION AND INFORMATIONAL ENTROPY IN RECONNAISSANCE DATA PROCESSING

**Abstract.** The reconnaissance data processing plays much role in warfare. The validity of this information is one of the most necessities for staff correct decision-making. Information entropy is a measure of data uncertainty. In information theory the concept of entropy describes how much information there is in signal or event. Information entropy relates to uncertainty amount concerning an event associated with given probability distribution. In this paper, the main importance of information entropy has been shown. In the same time, the application of both information entropy and expert evaluation methods in reconnaissance data processing has been considered. In consideration of the several sources of reconnaissance data, the calculation method of this information validity assessment has been offered on the basis of information entropy and expert evaluation.

**Keywords:** reconnaissance data processing; information entropy; data source; expert evaluation.

### Introduction

The reconnaissance data processing plays much role in warfare [1]. The validity of this information is one of the most necessities for staff correct decision-making. For solve this task the calculation of information entropy and expert evolutions [2] have been offered for processing of reconnaissance data and assessment of validity.

There are reasons to define information as the negative of the logarithm of the probability distribution in technical sense. The probability distribution of the events, coupled with the information amount of every event, forms a random variable whose expected value is the average amount of information, or entropy, generated by this distribution. Units of entropy are the Shannon, Nat, or Hartley, depending on the base of the logarithm used to define it, though the Shannon is commonly referred to as a bit.

It is known, that information entropy is data uncertainty measure [3, 4]. In information theory the concept of entropy describes how much information there is in signal or event. Information entropy relates to uncertainty amount concerning an event associated with given probability distribution. In this paper, the main content of information entropy is shown; the possibility of application of information entropy and expert evaluation in reconnaissance data processing has been considered; the method of entropy calculation for several sources got information has been offered.

### Information entropy

The concept of entropy in information theory describes how much information there is in a signal or event. Shannon introduced the idea of information entropy in his 1948 paper "A Mathematical Theory of Communication" [5, 6]. It was used for measurement of usefull information in signals transfer by use of wires. In general, Shannon's theory is used in investigations for various information transfer and store. In information science, the entropy is an information uncertainty measure. It equals to transfered information amount in the case of not information loss. If in communication channel an input signal equals absolutely to an output one, then it is means that entropy

equal zero, that is an entropy is absent. If there is not noise, then information is maximum.

The dependence of entropy on information is next:

$$H + Y = 1, \quad (1)$$

where  $H$  is entropy,  $Y$  is information.

It was obtained and justified by Leon Brillouin [7]. For entropy calculation K. Shannon had been offered the expression liked to Boltzmann's classic entropy:

$$H(A) = H(p_1 + \dots + p_n) = -\sum_{k=1} p_k \log_2 p_k, \quad (2)$$

where  $H$  is Shannon's entropy,  $p_k$  is a probability of some event [8].

Shannon's entropy defines quantitatively a validity of transfered information and it is used for calculation of information amount. The more amount of obtained information, the more data about this event (state), the less uncertainty and the less of entropy. Entropy has interesting properties and these special features confirm its amount measure uncertainty [8]:

1) entropy equals zero if only the probability of one event (state)  $p_1$  equals 1 (one) and the probabilities of other events (states)  $p_i$  equal zero; in all other cases entropy is positive:

$$(H(A) = 0 \Leftrightarrow p_1 = 1, p_2 = 0, \dots, p_n = 0) \wedge (H(A) > 0);$$

2)  $H$  is maximum for given  $n$  and it equals to  $\log_2 n$  when

$$p_1 = p_2 = \dots = p_n = 1/n; \quad (3)$$

3) if  $A$  and  $B$  are two independent random objects with number of  $n$  and  $m$  states, respectively, then

$$H(AB) = H(A) + H(B). \quad (4)$$

That is, entropy of two information equals to sum of two entropies of each informations.

When developing of obtained information, firstly, the special uncertainty of information is calculated:

$$I = -\log_2 p_n. \quad (5)$$

Then, the uncertainty of average information is calculated:

$$I_A = H(A) = -p_1 \log_2 p_1 - p_n \log_2 p_n. \quad (6)$$

Obtained results should be consider in information evaluation.

### Information entropy application in reconnaissance data processing

In consideration of above results, information entropy in reconnaissance data processing can be applied. Entropy of information about some event or state defines its reliability. When entropy calculation it should be consider another data and possibilities concerning this event or state. The information entropy nearer to zero, the more information reliability.

**Example 1.** Let us determine a special (attracted) information about enemy in "Tomorrow enemy's forces will attack" reconnaissance data. Let enemy can attack in any day of the week with the same probability and this probability is  $p = 1/7$ . The special information of this data is

$$I = -\log_2(1/7) \approx 2.81 \text{ bit.}$$

Therefore, the uncertainty of "Tomorrow enemy's forces will attack" data equals 2.81. There are two probabilistic states of events in above example. Let us adopt that  $A_1$  is the enemy's attack day and  $A_2$  is not the enemy's attack day. The probabilities of these state are

$$\forall A_1, p = 1/7; \quad \forall A_2, p = 6/7.$$

correspondingly.

Average information is

$$I_A = H(A) = -\frac{1}{7} \log_2 \frac{1}{7} - \frac{6}{7} \log_2 \frac{6}{7} \approx 0.59.$$

The uncertainty of average information of this data is 0,59. Usually, reconnaissance data about some of event (state) are obtained from several sources. Information entropies of various sources obtained data are calculated and then the average value is determined:

$$H_m = (H_{m1} + H_{m2} + \dots + H_{mn})/n. \quad (7)$$

**Example 2:** there have been obtained reconnaissance data from three sources:

- 1) from source  $m_1$  – "In some day of this week enemy's forces  $E$  will attack";
- 2) from source  $m_2$  – "Tomorrow enemy's forces  $E$  will attack";
- 3) from source  $m_3$  – "Tomorrow at 6 a.m. enemy's forces  $E$  will attack".

Let us calculate entropy of above given data:

$$H_{m1}(E) = -\frac{1}{7} \log_2 \frac{1}{7} - \frac{6}{7} \log_2 \frac{6}{7} \approx 0.59;$$

$$H_{m2}(E) = -\frac{1}{24} \log_2 \frac{1}{24} - \frac{23}{24} \log_2 \frac{23}{24} \approx 0.25;$$

$$H_{m3}(E) = -\frac{1}{60} \log_2 \frac{1}{60} - \frac{59}{60} \log_2 \frac{59}{60} \approx 0.12.$$

Thus, the average information entropy of data obtained about enemy  $E$  is

$$H_m = (0.59 + 0.25 + 0.12)/3 \approx 0.32. \quad (8)$$

The increasing of probability degree leads to decreasing information entropy and to increasing degree of data validity. For increasing the probability degree,

several questions should be determined and its answers should be found. For this purpose,  $n$  questions can be determined. But, for provide of rationality the minimum questions can be defined. For determination of probable event (state) realization by application of entropy calculation, the number of questions which demand answers, can be determined.

For instance, enemy want to attack at some of  $X$  day in interval  $[1 \div 7]$  days in this month,  $1 \leq X \leq 7$ .

The minimum questions should be given for "Eys" and "No" answers in purpose of revealing of this attack day. Let us determine information about  $X$  day in data. The probabilities of all  $X \in [1,7]$  days equal  $p_1 = p_2 = \dots = p_7 = 1/7$  and then  $I_X = -\log_2(1/7) \approx 3$ .

Thus, minimum 3 questions are necessary for attack day determination. Really, in this condition with equal probability "Eys" and "No" answers providing three questions are sufficient.

Let us consider that "4" day of the month is outline for attack and let us define questions:

**Question 1:** Is  $X$ -day nearly that "4"?

**Answer:** No.

**Result:**  $X$ -day is one of "4", "5", "6", "7".

**Question 2:** Is  $X$ -day nearly that "6"?

**Answer:** Yes.

**Result:**  $X$ -day is one of "4" or "5".

**Question 3:** Is  $X$ -day nearly "5"?

**Answer:** Yes.

**Result:**  $X$ -day is "4".

As it is shown, three questions allow to determine attack day in interval  $[1 \div 7]$  days.

Thus, by use of this method the tasks can be determined additional data necessary for reconnaissance forces and means.

### Expert avaluation application in reconnaissance data processing.

The consideration of experience results has importance sense in reconnaissance data processing, too. The additional information about frequency, sequence and other properties of some previously event (state) increases a certainty degree of data. The expert avaluation (opinion) is offered to apply in reconnaissance data processing by transforming it to quantitative state. The expert avaluation determines a degree of event probability. Below, it is offered a ranging of probable degrees based on the expert experience:

a full probability - 0,95;

a high probability - 0,8;

a medium probability - 0,5;

a low probability - 0,3;

a very low probability - 0,1).

The entropy of expert opinion can be calculated by below formula

$$H_e = -p_e \log_2 p_e$$

where  $H_e$  is an entropy of expert opinion,  $p_e$  is a probability of this expert opinion.

The expert opinion is agreed with obtained information in reconnaissance data processing and connected with event ( $M$ ) the average information

entropy is determined:  $H_M = H_m \cdot H_e$ , where  $H_m$  is the information entropy obtained from source.

For instance, in above pointed example 2, "Tomorrow at 6 a.m. enemy's forces  $E$  will attack" information is evaluated by the expert in consideration of previously experience. Then, the expert suggests that with high probability enemy forces will attack in the morning.

The entropy of expert opinion is:

$$H_e = -0.8 \log_2 0.8 \approx 0.25. \quad (9)$$

By the information entropy (8) and the expert entropy (9) mutual applied the average entropy of reconnaissance (degree of a validity) is

$$H_E = 0.32 \cdot 0.25 \approx 0.08.$$

Thus, the uncertainty of information is 0.08. That is, most probably this reconnaissance information is not correct.

### Conclusion

So, by applied of entropy in reconnaissance data processing, by mutual consideration of data from several sources and expert opinion, the validity of information obtained from war zone can be evaluated and recommended. Investigations have shown that mutual evaluation of the same time obtained information entropy and expert opinion entropy in processing of obtained from several sources reconnaissance data provides a high probability of degree of a validity of this information. The offered method has been demonstrated on the some examples.

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### Експертна оцінка та інформаційна ентропія в обробці розвідувальних відомостей

В. М. Мамедов

**Анотація.** Обробка розвідувальної інформації відіграє велику роль у військових діях. Обґрунтованість цієї інформації є найбільш необхідною для вірного прийняття рішення командуванням. Інформаційна ентропія це є міра невизначеності даних. У теорії інформації концепція ентропії описує кількість інформації в сигналі або події. Інформаційна ентропія встановлює кількісний зв'язок невизначеності, що стосується події, асоційований з даними про розподіл ймовірності. У даній статті показана велика роль інформаційної ентропії. Розглянуто одночасне застосування методів інформаційної ентропії та експертної оцінки в обробці розвідувальних даних. З урахуванням декількох джерел розвідувальної інформації, запропонований метод оцінки правдоподібності цієї інформації на основі інформаційної ентропії та експертної оцінки.

**Ключові слова:** обробка розвідувальної інформації; інформаційна ентропія; джерело інформації; експертна оцінка.

### Экспертная оценка и информационная энтропия в обработке разведывательных сведений

В. М. Мамедов

**Аннотация.** Обработка разведывательной информации играет большую роль в военных действиях. Обоснованность этой информации является наиболее необходимым для верного принятия решения командованием. Информационная энтропия это есть мера неопределенности данных. В теории информации концепция энтропии описывает количество информации в сигнале или событии. Информационная энтропия устанавливает количественную связь неопределенности, касающейся события, ассоциированную с данным распределением вероятности. В данной статье показана большая роль информационной энтропии. Рассмотрено одновременное применение методов информационной энтропии и экспертной оценки в обработке разведывательных данных. С учетом нескольких источников разведывательной информации, предложен метод оценки правдоподобия этой информации на основе информационной энтропии и экспертной оценки.

**Ключевые слова:** обработка разведывательной информации; информационная энтропия; источник информации; экспертная оценка.