

Enhanced Situational Awareness and Security Assessment in Surveillance Systems Using Cloud Model Theory

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DOI: 10.24086/cocos17.14

Abstract— Cloud Model Theory is a mathematical method to model the two components of uncertainty, Randomness and Fuzziness in linguistic concepts. This paper introduces a method to assess information, make and fuse decisions in multi-layered sensing systems using the cloud model to process uncertainty. In this research, Cloud model theory is used to model information extracted from digital images taken for the purpose of monitoring and surveillance in multi-layered sensing systems. The extracted information is assessed using the cloud models to make decisions about the level of security situations in the area under surveillance. The threat level of any security situation can be considered as concepts and can be modeled using cloud models to produce assessments; these assessments are then fused to make a decision about the level of the security threat. Cloud models provided a robust methodology to make decisions and evaluate security situations which led to enhanced situation awareness. Test results showed that cloud models performed much better in comparison with just using standard fuzzy logic models.

Keywords-Cloud Model Theory; Situation Awareness; Layered Sensing Systems; Information Assessment; Decision Making.

I. INTRODUCTION

The use of wireless sensor networks has expanded to many engineering application areas such as military applications, indoor and outdoor environmental monitoring, support for logistics, robotics, health systems, etc. [1, 2]. Military or civilian surveillance systems are designed to provide better situational awareness to the operators and decision makers. This task faces many challenges in terms of sensor technology, computation, communication, and human operators. The challenge of human operators is a serious limitation on using surveillance system efficiently because of tiredness, fatigue, lack of attention, etc. [3]. To solve this problem, attempts were made to introduce intelligence to surveillance systems in order to automate data fusion and information assessment especially in multi layered sensing systems [4].

Besides using probability theory to deal with uncertainty in information, new concepts were introduced to treat fuzziness and randomness in information. The efforts of Lotfi Zadeh has produced new concepts and a new way of thinking in human capability to do calculations using linguistic concepts without numbers. Humans don't have precise measurements when making a decision in a situation that requires

assessment. These new concept lead to new methodologies for information assessment such as computing with words and cloud computing. [5, 6].

The research described in this paper introduces one such attempt to assess information in a multi-layer surveillance system using cloud model theory to deal with the uncertainty in the information in order to make decisions about threat situations in an area under surveillance.

This paper is organized as follows; Section I will is an introduction to the subject, Section II will explain the cloud model theory, Section III will explain the methodology of extracting information from images and how to model it using cloud models, Sections IV discusses the results and the analysis of the results, Section V presents the conclusion of the research efforts, and finally future direction of the research area is presented in Section VI.

II. Theory of Cloud Modeling

Professor Deyi Li described a new method called cloud model theory to deal with randomness and fuzziness in a linguistic concept by creating a relationship between qualitative concepts and quantitative values. This model introduces a method to transform qualitative concepts to quantitative values [6]. The idea behind a cloud model states that any linguistic concept can be represented by a cloud graph and this graph can be utilized to get assessments about any data point of the information. The linguistic concept is defined as a cloud and any data point is defined as a cloud drop [6]. The summary of the cloud model theory states that if (C) is a quantitative concept that is represented by the set of numbers (U). if we take a number (x) which is a member in (U) and realizes the concept (C) then the confidence degree of (x) for (C) is defined by a random value $\mu(x)$ which is between 0 and 1. This random value has a stabilization tendency shown in equation 1.

$$\mu: U \rightarrow [0,1] \quad \forall x \in U \quad x \rightarrow \mu(x) \quad (1)$$

The distribution of x is represented by a cloud, and every x represents a cloud drop [6]’.

In a cloud model, the properties of any concept can be represented by the numerical characters which are the overall quantitative property of the qualitative concept. In every cloud model three numerical characters can be employed: Expected value (E_x) which is the mathematical expectation of the cloud drop distribution, Entropy (E_n) which is the uncertainty in the concept, and Hyper Entropy (H_e) which is the second order entropy of the entropy [6]. Cloud models can be represented by Cloud graphs such as in Figure 1.

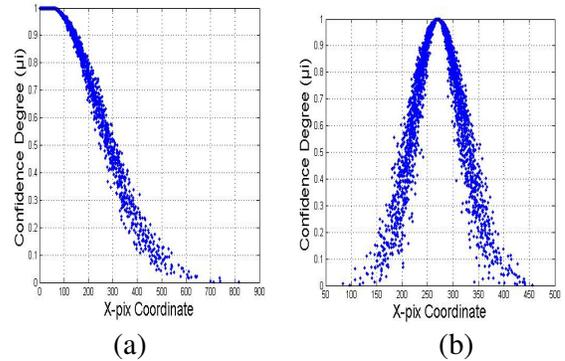


Fig. 1 Cloud Models Graphs:

- (a) Half Cloud Model.
- (b) Symmetrical Cloud Model.

How to create a Cloud Model: Cloud models can be created by using a forward and backward cloud mapping. A Forward cloud creation is the transition from quality (concepts) to quantity (values). This is done by representing the numerical characteristics of a concept (E_x, E_n, H_e) in a cloud graph. The cloud graph can contain a number of cloud drops (x_i) with known confidence degrees ($\mu_i(x_i)$). Backward cloud creation is the transformation from a quantitative value to a qualitative concept. In this cloud creation a number of (x_i) is selected and its confidence degree ($\mu_i(x_i)$) is extracted. The confidence degree ($\mu_i(x_i)$) is calculated by using equation (2) [6].

$$\mu_i = e^{-\frac{(x_i + E_x)^2}{2(Rn)^2}} \quad (2)$$

(Rn) is a random number generated from a normal distribution function.

III. SITUATION AWARENESS IN SURVEILLANCE SYSTEMS

Surveillance systems have advanced from monitoring camera systems using human observers to smart surveillance systems where advanced techniques and algorithms are used to help the human observer determine the threat level of any situation under surveillance. These systems still lack some decision making capability that can substitute the absence of human observer. The main objective of these surveillance systems is to provide complete situation awareness about any security threat that faces any facility under surveillance.

The research presented in this paper presents a new methodology to assess any situation under surveillance in terms of threat level. In this method a mathematical model is built based on the cloud model theory and is used to assess the threat level of any situation. This is done automatically and this way a new level of intelligence is added to the surveillance system. This provides a decision making capability that can be used to increase situation awareness for the system.

In this research cloud models were developed to assess the threat level. The assessment started with identifying security concerns as linguistic concepts for the areas under surveillance. The security concerns which were selected for experiments were geographical areas under surveillance and the objects in these areas. To create a cloud model for areas of interest, parts of the area were selected based on borders on the ground and these borders were modeled into a cloud model from an initial setting or an image. Objects in these areas were modeled into cloud models based on their identified features.

To create the cloud models, initial pictures were studied of the areas of interest and security concerns were identified and the mathematical characteristics (E_x, E_n, H_e) were determined. A cloud graph was developed for each security

concept and object of interest. An example of such process is shown in Figure 2.

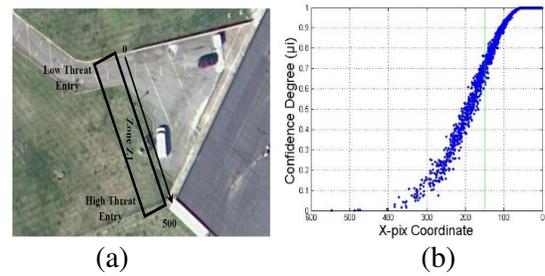


Fig. 2 developing cloud models for security concerned areas.
(a) Initial picture of an area under surveillance.
(b) Cloud model developed for area.

Information Assessment from security areas: The methodology for assessing threat level information from the security areas involved taking images from the area under surveillance and provide information extracted from the images to the cloud models designed for the that area to assess security concerns or objects features. The assessment involved determining confidence degree $\mu(x)$ for each threat level. Based on these assessments, a decision was made about threat levels for any event that happens in the area under surveillance.

In multi-layer surveillance systems, information assessments from different layers were fused for the same event to enhance the decision making process about threat level of an event.

Assessments from different layers can be combined using a two dimensional cloud model. The two dimensional cloud combines two confidence degrees using a soft – and logic instead of Boolean Logic.

IV. RESULTS AND ANALYSIS

The methodology of using cloud models for information assessment was implemented in a three layer surveillance system. Areas under surveillance were monitored from three layer camera system where images were taken of the area and analyzed for information that was used in the cloud models for assessment. Areas under

surveillance were classified into security zones and object features in these areas were identified and used to extract information from the images taken in these areas. Threat level assessment was classified into categories of threats ranging from low threat to high threat and each was assigned a range of confidence degree associated with uncertainty level.

To compare and analyse the cloud model theory based information assessment system, a parallel information assessment system was developed using standard fuzzy logic. The same information extracted from the images were assessed using both systems. From the analysis of the results of the tests scenarios carried out in both systems, the result showed that the cloud model based system performed much better than the traditional systems that are based on only fuzzy logic. The results were assessed from the human point of view about the decision made by the systems in terms of security situations the results showed that the cloud mode system missed the right assessment in 18% of the test scenarios only which shows that cloud model based system can obtain better results because of dealing with the information uncertainty with both elements of randomness and fuzziness present in the analysis. Results of the test scenarios are shown in Figure 3.

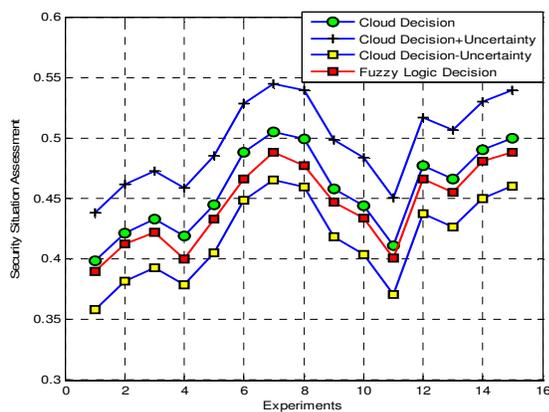


Fig. 3 Cloud Model and fuzzy Logic decision making comparison.

V. CONCLUSION

The objective of this research was to introduce a new methodology to autonomously assess information with uncertainty in multi-layer surveillance systems. The purpose of the information assessment was to help human operators and decision makers to detect threat levels more accurately.

Information assessment and decision making capabilities provided by the cloud model theory system produced accurate and acceptable results. Cloud models deployed in the system provided a way to treat the uncertainty in the information that every decision making system faces. The cloud model theory has an advantage because it can map quantitative concepts to qualitative mathematical models by combining information fuzziness and randomness in the same model.

The proposed system performed better in experiments compared to a similar system using only fuzzy logic to assess the information. This methodology of using cloud models for assessing information could be expanded to be used in many other areas when uncertainty is part of the information. One such area for using the cloud models is to develop a control mechanism for data quality control for heterogeneous sensor networks.

VI. FUTURE WORK

Adding a higher level of intelligence to systems has a great potential and is the a wide area of research in the field of intelligent control systems such as surveillance systems, manufacturing systems, automation systems, robotic systems, embedded systems, etc. It is the intention of the researchers here to continue the work in this area to develop a robust algorithm and methodology to introduce intelligent control systems for many applications such as irrigation systems, traffic control systems, home security, commercial surveillance systems, etc.

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