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Effective Video Analysis Preprocessing Algorithm Based on Rough Sets in Compressed Domain*

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Abstract: This study is aimed to overcome the characteristic of redundant data for video analysis, the study propose a video analysis preprocessing algorithm based on Rough Sets (RS). Firstly, the representative data of video sequences is extracted. Secondly, the Information Table is constructed by extracted representative data. Finally, the Core of Information Table is achieved by making use of the attributes reduction theory of RS. As present experimental results indicate, the algorithm can get effective and scientific data to complete video analysis such as key frame extraction and shot segment. Compared to existing techniques, thr proposed algorithm enjoys following advantages. Only a subset of frames need to be considered during video analysis. The limitations of requirements for a huge amounts of memory and CPU resource is overcome.

Key words: Attributes reduction, core, information system

INTRODUCTION

Advances in computer, telecommunications and internet technologies have brought huge amounts of multimedia information to a rapidly growing. More and more digital videos are made available over the internet or other storage device. Since of the characteristics of redundancy information in video data, many video analysis technologies become less available, especially in real-time system. So, video data preprocessing become an important and imperative work before video analysis.

There have been many considerable work reported on video preprocessing. All in all, the existing typical techniques can be categorised into following types: Video shot segmentation based technologies (Cooper *et al*., 2007; Lee *et al*., 2006), key frame extraction based technologies (Shuping and Xinggang, 2005; Kin-Wai Sze *et al*., 2005) and video summarization based technologies (Wen-Nung and Chun-Ming, 2004; Yu-Fei and Hong-Jiang, 2002). A challenging and difficult problem of above technologies is there is no efficient and scientific algorithm to processing redundant data either in uncompressed domain or compressed domain.

Rough Set (RS) is a novel and powerful tool for data analysis. It has successfully been used in many application domains, such as machine learning, expert system and pattern classification (Wojciecn *et al*., 2008; Neil and Qiang, 2008). The main advantage of rough sets is that it does not need any preliminary or additional information about data, like probability in statistics, or basic probability assignment in Dempster-Shafer theory and grade of membership or the value of possibility in fuzzy sets. Especially, the attributes reduction theory has widely used in many application domain

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(Changzhong *et al*., 2008; Yiyu and Yan, 2008). In this study, by using the advantage of RS theory, a RS based video analysis preprocessing algorithm is developed.

ROUGH SETS THEORY

Basic Concepts of Rough Sets

An Information System is a 4-tuple S = (U, A, V, F), where U non-empty finite set of objects, A is a non-empty finite set of attributes, V is the union of attributes domains.

Let $U \neq \phi$ be a universe of discourse and X be a subset of U. An equivalence relation, R, classifies U into a set of subsets $U/R = \{X_1, X_2, \ldots X_n\}$ in which the following conditions are satisfied:

- $X_i \subseteq U$, $X_i \neq \phi$ for any i
- $X_i \cap X_j \neq \phi$ for any i, j
- $\bigcup_{i=1, 2, \ldots, n}, X_i = U$

Any subset X_i, which called a category, class or granule, represents an equivalence class of R. A category in R containing an object $x \in U$ is denoted by $[x]_R$. For a family of equivalence relations $P \subseteq R$, an indiscernibility relation over P is denoted by IND (P) and is defined by Eq. 1:

$$IND(P) = \bigcap_{R \in P} IND(R) \tag{1}$$

The set X can be divided according to the basic sets of R, namely a lower approximation set and upper approximation set. Approximation is used to represent the roughness of the knowledge. Suppose a set $X \subseteq U$ represents a vague concept, then the R-lower and R-upper approximations of X are defined by Eq. 2 and 3.

$$\underline{R}X = \{x \in U : [x]_R \subseteq X\} \tag{2}$$

Equation 3 is the subset of X, such that X belongs to X in R, is the lower approximation of X.

$$\overline{R}X = \{x \in U : [x]_R \cap X \neq \phi\} \tag{3}$$

Equation 3 is the subsets of all X that possibly belong to X in R, thereby meaning that X may or may not belong to X in R and the upper approximation $\overline{R}$ contains sets that are possibly included in X. R-positive, R-negative and R-boundary regions of X are defined respectively by Eq. 4, 5 and 6.

$$POS_R(X) = \underline{R}X \tag{4}$$

$$NEG_R(X) = U - \overline{R}X \tag{5}$$

$$BNR(X) = \overline{R}X - \underline{R}X \tag{6}$$

The positive region includes all objects in U which can be classified into the equivalence classes determined by indiscerniblility relation.

Attributes Reduction and Core

In RS theory, an Information Table is used for describing the object of universe, it consists of two dimension, each row is an object, and each column is an attribute. RS classifies the attributes into two types according to their roles for Information Table: Core attributes and redundant attributes. Here, the minimum condition attribute set can be received, which is called reduction. One Information Table might have several different reductions simultaneously. The intersection of the reductions is the Core of the Information Table and the Core attribute are the important attribute that influences attribute classification.

A subset B of a set of attributes C is a reduction of C with respect to R if and only if:

- $POS_B(R) = POS_C(R)$
- $POS_{B-\{a\}}(R) \neq POS_C(R)$, for any a∈b

And the Core can be defined by Eq. 7:

$$CORE_C(R) = \{c \in C \mid \forall c \in C, POS_{C-\{c\}}(R) \neq POS_C(R)\} \quad (7)$$

THE PROCEDURE OF DATA PREPROCESSING

Acquisition of Raw Data

Raw video data come from two aspects, the first is come from uncompressed domain, i.e., the frame in original video sequences. In this case, each video frame can be represented by the three primary colors of RGB. The second is come from compressed domain. In this case, the data is come from I, P and B frame. To simplify processing model, we only consider the I frame, i.e., DCT coefficients and DC coefficients. The DCT coefficients and DC coefficients can be acquisited easily by Eq. 8 and 9.

$$\psi(P(x),t) \xrightarrow{\text{extract}} \text{DCT coefficients} \quad (8)$$

$$\text{DCT cofficients} \xrightarrow{\text{reprecessing}} \text{DCT coefficients} \quad (9)$$

Equation 8 shows the DCT coefficients can be extracted from I frame of each video sequences. And Eq. 9 shows that by eliminating the AC coefficients of each block, the DC coefficients can be extracted.

The Construction of Preprocessing Model

According to MPEG video compressed standard, DC coefficients represent the major visual information of video sequences. As such, DC coefficients can satisfy the requirements of video analysis sufficiently. We have got the DC coefficients of each frame, so we can construct an Information System with it. Each row is a DC coefficient, and each column is the frame. This process can be described as following Eq. 10.

$$\text{DC} \xrightarrow{\text{reprecessing}} \text{Information Table } S=\{U, A, V, f\} \quad (10)$$

where, U is sets, denotes all the object of Information System, A is also a sets, denotes all attributes in Information System, V is the sets of attributes value, f is a function denotes the relations between objects and attributes.

By using above process, we can get Information System table as Table 1. In Table 1, each row represent the DC coefficients of block in various video frame, consequently, this table contained the first and most important information of video sequences.

Table 1: Information system table constructed using DC coefficients

DC coefficient	Frame 1	2	3	4	5	6	7	8
DC1	0.35355	0.35355	0.27771	0.35355	0.41572	0.35355	0.35355	0.35355
DC2	0.35355	0.35355	0.27779	0.35355	0.41573	0.35354	0.35355	0.35355
DC3	0.35355	0.35355	0.27779	0.35356	0.19134	0.35355	0.35355	0.35355
DC4	0.35356	0.35356	0.27779	0.35355	0.19134	0.35351	0.35355	0.35355
DC5	0.35355	0.35355	0.27779	0.35355	0.19134	0.35336	0.35355	0.35355
DC6	0.27779	0.27779	0.27779	0.35356	0.19134	0.35345	0.35355	0.35355
DC7	0.27779	0.27779	0.27779	0.35355	0.19134	0.35353	0.35355	0.35355
DC8	0.23761	0.23761	0.27779	0.35355	0.35355	0.35355	0.35355	0.35355

Table 2: The reduced information system

DC coefficient	Frame 1	3	4	5	6	7
DC1	0.35355	0.27771	0.35355	0.41572	0.35355	0.35355
DC2	0.35355	0.27779	0.35355	0.41573	0.35354	0.35355
DC3	0.35355	0.27779	0.35356	0.19134	0.35355	0.35355
DC4	0.35356	0.27779	0.35355	0.19134	0.35351	0.35355
DC5	0.35355	0.27779	0.35355	0.19134	0.35336	0.35355
DC6	0.27779	0.27779	0.35356	0.19134	0.35345	0.35355
DC7	0.27779	0.27779	0.35355	0.19134	0.35353	0.35355
DC8	0.23761	0.27779	0.35355	0.35355	0.35355	0.35355

Reduced Sets and Core

The attributes in the Information Table can be divided into two types by their roles: Core attributes and redundant attributes. From Table 1, we can show that the frame 2 and frame 8 can be reduced, the reduced Information System is showed as Table 2. If we introduce a threshold, more attributes can be reduced.

By attributes reduction, we can get a succinct and informative Information Table, this Table 2 contain major visual information of video sequences, so it is sufficient to utilize the table to video analysis.

The Description of Algorithm

```
algorithm: Generate_core(GC)
input: Original Information Table
output: Reduced attributes sets
processing:
        (1)
        for i = 1 to n //n is the number of Information Table recorder
        {
        for j = 1 to m //m is the number of Information Table attributes
          {
            if p_ik = p_jk //k = 1,2…n
        m_ij = Φ
        else
            m_ij = {a    A|f(x_i,a) ≠ f(xj,a)} i, j = 1,…n //m_ij is the sets of all attributes that can discern x_i and x_j
}
}
        (2)
          for i = 1 to n
          {
              for j = 1 to m
          {
    if and [x_i]A∩⌊x_j⌋A = Φ
          output A
          }
}
```

EXPERIMENTAL RESULTS

Various MPEG video sequences are selected to examine the performance of proposed algorithm. Figure 1 illustrates some key frames extracted from shots using proposed algorithm. Figure 2 show some shots extracted from experimental video sequences using our proposed algorithm. We can see obviously that the data can complete the video analysis efficiently. Table 3 and 4 show the comparison results.

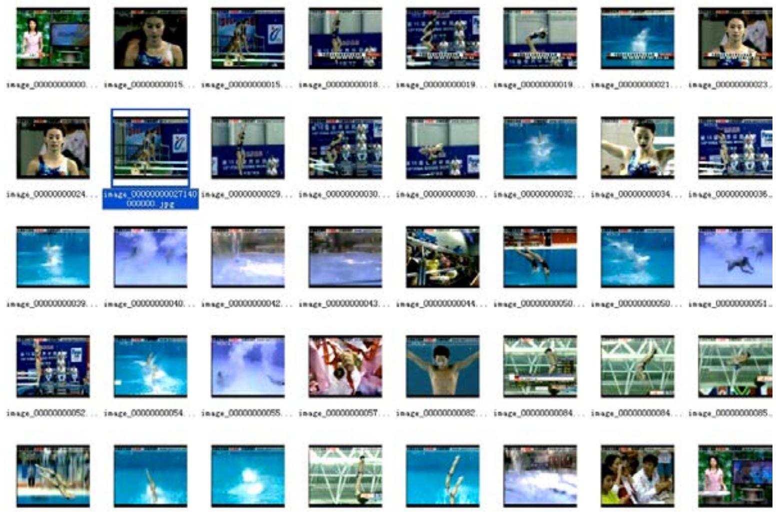

Fig. 1: Some key frames extraxted from shots using proposed algorithm

Fig. 2: Shots extracted from experimental video sequences using our proposed algorithm

Table 3: Comparison results of shot boundary detection by various video sequences

Video sequences type	Before preprocessing Frames	Before preprocessing Shots	After preprocessing Frames	After preprocessing Shots	Error detected	Results evaluations
Gym	112	7	31	6	1	Excellent
Animation	174	13	53	14	1	Excellent
Scenery	317	23	106	23	0	Good
Story	126	13	97	13	0	Excellent
News	153	14	101	17	3	Good

Table 4: Comparison result of key frame extraction by various video sequences

Video sequences type	Before preprocessing		After preprocessing		Error detected	Results evaluations
	Frames	Key frame	Frames	Key frame		
Gym	112	26	31	30	4	Excellent
Animation	174	47	53	52	5	Excellent
Scenery	317	69	106	83	14	Good
Story	126	50	97	52	2	Excellent
News	153	81	101	84	3	Good

With above comparison and evaluation, we can see obviously that preprocessed data can satisfy the video analysis for key frame extraction and shot segmentation, while the amounts of the frames and the data of each frame are reduced dramatically. As such, the efficiency is improved.

CONCLUSION

As the characteristics of video stream data, the first and most difficult task in video analysis is how to process redundant data. In this study, we propose a effective and efficient video analysis preprocessing algorithm based on rough sets in compressed domain. The algorithm introduce concepts of rough sets theory, the amount of data is reduced dramatically and scientifically. The experimental results prove that proposed algorithm can process video such as key frame extraction or shots segment without considering full data.

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