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Incremental Approach for Updating Approximations of Variable Precision Rough Set Based on Dominance Relations

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Abstract: Variable precision rough set (VPRS) based on dominance relation is an extension of traditional rough set by which can handle preference-ordered information flexibly. This paper focuses on the maintenance of approximations in dominance based VPRS when the objects in an information system vary over time. The incremental updating principles are given as inserting or deleting an object, and some experimental evaluations validates the effectiveness of the proposed method.

Introduction

Rough set theory [1] is a powerful mathematical tool to process inconsistent information. After it was proposed by Pawlark, traditional rough set has been extended from different angles. The first group is extended models based on equivalence relations including variable precision rough set (VPRS) model [2], probabilistic rough set model [3], and decision model of rough set [4]. The second group is compatibility relation-based rough set models [5] which extend the equivalence relation to compatible relation. The third one is dominance based rough set models [6] where the equivalence relation is extended to dominance relations for dealing with preference ordered information. The fourth one includes a mix of several models such as variable precision tolerance rough set model, variable precision probabilistic rough set model, dominance-based variable precision rough set model, etc.

Dominance-based variable precision rough set models extend traditional equivalence relations to dominance relations and combine the concept of variable precision to relax the lower and upper approximations. In this paper, we define an extended dominance relation to further relax the definition of dominance relation. Then we focus on the maintenance of the lower and upper approximations of a given concept in a dynamic information system. Two types of variations of the object set are considered including the insertion or deletion of an object. In the literature, many scholars put forward efficient incremental approaches for updating approximation set under the variation of object set[7,8,9]. Up to date, we do not find any report of incremental methods for maintaining approximations of dominance-based VPRS models.

Basic Concepts

Definition 1. (Dominance set /dominated set of VPRS) Let $\alpha > 0.5, M = [\alpha \bullet m]$, Where M denotes the number of attributes, and $P \subseteq C$ is a subset of conditional attributes. The dominance set /dominated set of VPRS based on extended dominance relation are defined as follows:

$$D_{P_\alpha}^{+}(x_i)=\left\{x_j \in U : \phi_{ji}^{P} \geq M\right\} \qquad D_{P_\alpha}^{-}(x_i)=\left\{x_j \in U : \phi_{ji}^{P} < M\right\}$$

where ϕ^P is the dominance matrix with respect to attribute set P.

Definition 2. (Lower and upper approximation set) Let $\beta > 0.5$, X is a subset of the universe U, and then the approximation sets of a given subset of objects X are defined as:

Lower approximation set: $\underline{R}_{\beta}^{\leq}(X)=\{x\in U : \frac{\left|D_{P_\alpha}^{+}(x)\cap X\right|}{\left|D_{P_\alpha}^{+}(x)\right|} \geq \beta\}$;

Upper approximation set: $\overline{R}_{\beta}^{\leq}(X)=\{x\in U : \frac{\left|D_{P_\alpha}^{+}(x)\cap X\right|}{\left|D_{P_\alpha}^{+}(x)\right|} \geq 1-\beta\}$.

For convenience, in the following section, use $c(x,X)$ to denote $\frac{\left|D_{P_\alpha}^{+}(x)\cap X\right|}{\left|D_{P_\alpha}^{+}(x)\right|}$.

Updating Principles of Set Approximations

In this section, we discuss the update principles when inserting or deleting an object respectively. Let x^+, x^- denote the inserted and removed objects; U', X' the updated universe and the given subset of objects; $\underline{R}_{\beta}^{'\leq}(X)$ and $\overline{R}_{\beta}^{'\leq}(X)$ the updated lower/upper approximations. Due to the limit space of this paper, we omit the proofs of all propositions.

1. Insertion of an object

Proposition 1. $x^+ \notin X, X' = X$,

$$\underline{R}_{\beta}^{'\leq}(X)=\underline{R}_{\beta}^{\leq}(X)\cup\left\{x^+ \mid c(x^+,X')\geq\beta\right\}-\left\{x \mid x^+\in D_{P_\alpha}^{+}(x), x\in \underline{R}_{\beta}^{\leq}(X)\,\&\, c(x,X')<\beta\right\}$$

Proposition 2. $x^+ \in X, X' = X\cup\left\{x^+\right\}$

$$\underline{R}_{\beta}^{'\leq}(X)=\underline{R}_{\beta}^{\leq}(X)\cup\left\{x^+ \mid c(x^+,X')\geq\beta\right\}\cup\left\{x \mid x^+\in D_{P_\alpha}^{+}(x), x\notin \underline{R}_{\beta}^{\leq}(X)\,\&\, c(x,X')\geq\beta\right\}$$

The principles of updating upper approximation set are completely similar to those of lower approximations. We only need to replace β with $1-\beta$ in above propositions 1-2.

2. Removal of an object

Proposition 3. $x^- \notin X, X' = X$,

$$\underline{R}_{\beta}^{'\leq}(X)=\underline{R}_{\beta}^{\leq}(X)-\left\{x^- \mid x^-\in \underline{R}_{\beta}^{\leq}(X)\right\}\cup\left\{x \mid x^-\in D_{P_\alpha}^{+}(x), x\notin \underline{R}_{\beta}^{\leq}(X)\,\&\, c(x,X')\geq\beta\right\}$$

Proposition 4. $x^- \in X, X' = X-\left\{x^-\right\}$,

$$\underline{R}_{\beta}^{'\leq}(X)=\underline{R}_{\beta}^{\leq}(X)-\left\{x^- \mid x^-\in \underline{R}_{\beta}^{\leq}(X)\right\}-\left\{x \mid x^-\in D_{P_\alpha}^{+}(x), x\in \underline{R}_{\beta}^{\leq}(X)\,\&\, c(x,X')<\beta\right\}$$

By replacing β with($1-\beta$)in propositions 3-4, we obtain the principles of updating upper approximation set.

Experimental Evaluation

In this section, we use eleven UCI data sets to validate the effectiveness of our proposed incremental methods under variations of object set. These data sets are summarized in Table 1. The incremental algorithms and the non-incremental algorithm are coded by MATLAB(R2010a) and run on a personal computer with Windows 7 and Inter(R) Core (TM)2 Duo CPU E7500 @2.93GHz and 2.00GB memory.

The inserted or removed object is selected randomly from the data sets, and the experimental results are shown in Fig. 1 and Fig. 2. The above lines in the two figures are the computation time of original non-incremental method when adding or deleting an object; while the lines below (ZJincremental, SCincremental) is the computation time of incremental method when adding or deleting an object. It can be easily seen from the figures that the computation time of incremental method is far less than the traditional non-incremental method. When any variation occurs, the original method needs to recalculate each dominance set of every object and then compute the upper and lower approximation sets. By contrast, the incremental method reuses the current information of dominance matrix, dominance set, and current approximation sets. It only needs to add or delete one or several objects from original approximation set, which greatly reduces the updating time.

Table 1: Data sets

Data sets	Number of rows	No. of attributes	No. of classes	Data sets	No. of rows	No. of attributes	No. of classes
Hayes	132	6	3	Breast	569	32	2
Iris	150	5	3	Balance	625	5	3
Wine	178	14	3	Pima	768	9	2
Haberman	306	4	2	Connectionist	991	14	11
Liver	345	7	2	Yeast	1484	9	10
Climate	540	20	2				

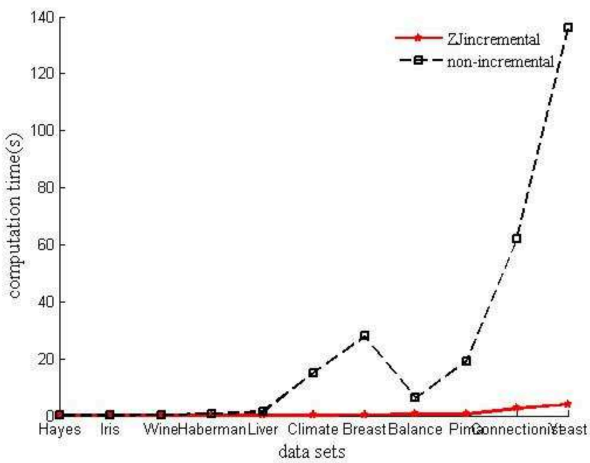

Fig. 1. Insertion of an object

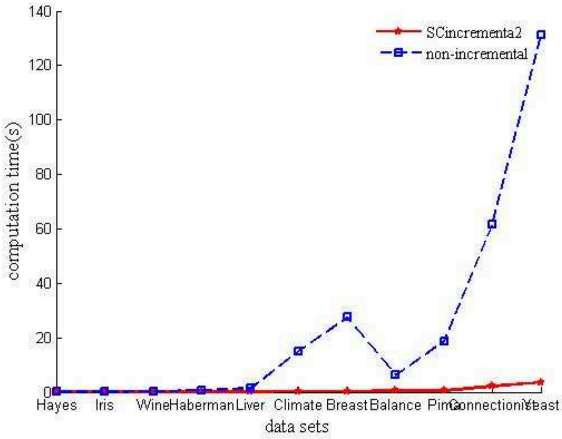

Fig. 2. Removal of an object

Conclusions

In this paper, the dominance relation is extended and proposed variable precision rough set based on extended dominance relation, then consider the updating of approximation sets when deleting or adding an object. The main purpose is to reduce computation time.

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