A Method to Find Learner's Key Characteristic in Wed-Based Learning

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Abstract. One of the challenges in personalized e-learning research field is how to meet the unique learning strategies according to a learner's personality characteristic. But a learner's characteristic may have many attributes, and some of them have not equal value for personalized e-learning. This paper exploits the aspect to evaluate the important attributes, puts forward the concept of key personality characteristic and an improved algorithm basing on rough set theory to find the key attributes. Systematic experiments and their results are reported and shows the dimensions of personality characteristic can be decreased to below one-quarter.

1 Introduction

Because of its flexibility and cost-effectiveness, e-learning has become a vital complement to the traditional classroom learning. The research of personalized e-learning is an important topic in education and computer science fields. Some fundamental learning theories show that learning strategies are vital aspects of personalized learning [1] and the study in educational psychology shows that learning strategies are greatly affected by the learner's personality characteristic [1][2].

Personality characteristic refer to somebody's relatively stable traces that are revealed internally or externally. Physiologically, these characteristic include physical signs and human senses etc. Psychologically, these characteristic include intellectual types, personal interests, motivation, emotion and will etc.

However, the relative importance of these attributes does not have equal weights to learning strategies. Some attributes are even redundant. If we consider all attributes in personalized e-learning, then when the number of learners in a study group is large in quantity, we may encounter the problem of "dimension disaster". One example will be an e-learning university where thousands of students are enrolled and each of them needs hundreds of attributes to describe his/her characteristic and finding appropriate strategies for each student quickly are a hard problem in the situation. Therefore, it is an important research problem to reduce the number of attributes so that only key attributes are identified and used in the search for appropriate learning strategies in personalized e-learning environment. This article presents the results of a research project that sought to explore learner's key characteristic attributes and determine the relative weight of each attribute.

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The experiments and analysis, in Section 5, showed that the concept of key personality characteristic and the analysis method, we put forward in the paper, are efficient to solve the problems of dimension disaster and huge data volume in personalized e-learning environment. For the sample data set, the initial personality characteristic have 28 dimensions and, after processed, the dimensions of key personality characteristic attributes can be decreased to below one-forth and the reduction rate of data volume can mostly be about 50%.

2 Related Work

Nowadays there are some studies on the relationship among learner's characteristic and the learning strategies. Most of them are from the perspective of educational psychology. The methods used by them are correlate analysis, regression analysis and discriminator function [7][8]. These only focus on the correlation study, but which attributes are key and which are redundant (i.e., they are the target for reduction) still involved human experts to determine and the process is subjective and wastes time.

Furthermore, most researches simply study the relation between the single attribute and learning strategies and did not considerate the whole influence of the combination of attributes to the strategies. Moreover, some method, such as regression analysis, can not be applied when the attributes have interrelation each other. While, traditional statistical methods are employed to handle massive data set in e-learning.

Rough set is a relatively new mathematically method to handle imprecise, non-deterministic and incomplete data. In recently years, it has been applied to areas like machine learning, knowledge discovery, data mining and decision support [4][6]. The inference process of the rough set naturally simulates the self-adaptive behaviors and characteristic existed in human beings. The key advantage of the rough set approach over other ones is that there is no need for prior knowledge. It is able to reveal the natural relationship through data itself [5].

In the paper, a new approach was presented to study how to fine the learner's key attributes influencing the learning strategies. The method first constructed information system for learners' personality characteristic, then applied an improved algorithm basing on rough set theory, which directly built core set and non-core set and calculated the reducts basing on the logical calculation to obtain the attribute reducts, and, at last, analyzed and compared the results, and found the learner's key characteristic attributes and obtained their weights.

3 Concepts and Definitions

Many educational psychology researches and practices show that personality factors, learning styles and learning conceptions have influences on the learning strategies[2], so in this paper, personality characteristic include these. Personality factors are representative of the affective and cognitive aspects of individual traits. Recent decade's research results in psychology field show that investigating personality factors help predict a person's learning patterns and strategies[2]. Learning styles denote cognitive styles observed specifically in a learning context. Cognitive styles are tendencies that

are consistently displayed by individuals to adopt a particular type of information processing strategy. Learning conceptions are a person's conceptions and ideas about what learning is. It is believed to have a strong impact on learning strategy use[2].

There is still a debate among about the definition of learning strategy in education and educational psychology. Our understanding of the learning strategy is mainly based on the experiences gathered through the study of foreign language (main English) at Xi'an Jiaotong University, China. In Chinese universities, College English is a required course for almost all students. Here, to make the study more effective and not be too general to be valuable, we take English language learning into account, and accordingly, personality characteristic include personality factors, language learning styles and language conceptions, and learning strategies include metacognitive strategy, affective strategy, form-focused strategy, meaning-focused strategy, compensation and social strategy[3].

To make expatiate smoothly and avoid different comprehension in meanings, some definitions are explained in details as following.

Definition 1. Personality characteristic

A learner's personality characteristic is the relatively stable traces that are revealed internally or externally. As the above, in this paper, personality characteristic include personality factors, language learning styles and language conceptions and it can be represented as C = {PF, LS, LC}. C is the whole attribute set for personality characteristic. PF is the attribute subset for describing personality factors and one example is 16 PF identified by Raymond B. Cattell in the 1940s. LS is the attribute subset for describing the language learning styles, such as visual, audio or experimental types. LC is the attribute subset for describing the language conception such as self-management in a learning environment. The details are showed in Appendix. In the case, personality characteristic have 28 dimensions at least.

Definition 2. Learning strategies

As the above, taken English language learning into account, learning strategies can be described in the following five aspects: metacognitive strategy, affective strategy, form-focused strategy, meaning-focused strategy, compensation and social strategy[3].

Metacognitive strategy refers to plan the organization of one's learning, such as establishing the goal for learning, making a schedule, etc. Affective strategy refers to control one's affection during learning, such as encourage oneself when feeling depressed. Form-focused strategy refers to the concrete approach to mastering the knowledge, such as memorizing the words by reciting. Meaning-focused strategy refers to practice the ability of reading, speaking, listening, etc., such as improving listening ability by listening to the foreign language radio. Compensation and social strategy refers to methods during one's communication with others, such as gesturing when one can not express any words.

Learning strategies can be described as $D = \{mcs, afs, ffs, mfs, css\}$, where *mcs* is the abbreviation for metacognitive strategy, *asf* is for affective strategy, *ffs* is for form-focused strategy, *mfs* is for meaning-focused strategy and *css* is for compensation and social strategy.

Definition 3. Information system for learners' personality characteristic（SLPC）
The construction of an information system for learners' personality characteristic is the foundation for analyzing key characteristic attributes. The information system is the set of learners. The set can be represented as $S = (U, C \cup D, V, f)$. U is the non-empty finite set for all the learners. C is the non-empty finite set for personality characteristic attributes of learners. D is the non-empty finite set for the learning strategies, such as metacognitive strategy, and affective strategy etc. $C \cap D = \varnothing$, $C \cup D = A$, $V = \bigcup_{a \in A} V_a$, V_a is the value domain for $a \in A$ $f : U \times A \to V$ is a single mapping function such that there is a unique value in V for all $a \in A$.

Definitions 4. Reducts of the set of personality characteristic
Reducts of the set of personality characteristic are the results of the approach, applied in this paper, and the reduction is the process through which characteristic attributes, that have little influence on the learning strategies, are eliminated, according to the implicit relationship among characteristic attributes and the learning strategies.

In rough set theory, suppose $R \subseteq C$, $X \subseteq U$, $\underline{R}X = \left\{ x \in U \mid [x]_{ind(R)} \subseteq X \right\}$ is the R-Lower approximation of X. Suppose $pos_R(D) = \bigcup_{X \in U/D} (\underline{R}X)$ is R-positive region of D. It is essentially the union set of all objects of U, which can be classified into U/D using the learners' personality characteristic subset R. If $\alpha \in R$, $pos_R(D) = pos_{R-\{a\}}(D)$, then α is redundant in R. Otherwise, α is necessary in R. If every α in R is necessary, R is independent of D. That is to say, for given information system of learners' personality characteristic S, the rough set C' is a non-empty subset of C such that (1) $pos_{C'}(D) = pos_C(D)$, (2) If C' is the C-independent subset of D, C' is the C-relative independent rough set of D. $red_D(C)$ represents the set of all reductions. The core of C is defined as the intersection of all reductions of C: $core_D(C) = \cap red_D(C)$.

Definition 5. Key attributes of personality characteristic
Key attributes of personality characteristic are the ones that have relatively importance value related to the learning strategies. If $\alpha \in C'$, The influence factor of α is defined as

$$SGF(a, C', D) = (| pos_{C'}(D) | - | pos_{C'-\{\alpha\}}(D) |) / | U |.$$

If $SGF(a, C', D)$ is $\geq 97\%$, α is the key attribute. Otherwise, α is not.

Definition 6. Discernibility function
If $a_i \in C$, $x, y \in U$ and belong to different equivalent sets of $d_i \in D$, $a(x, y) = \{a_1, a_2, \ldots, a_k\}$ represents the subset of C and $a_i \in C$ can differentiate

x and y in U (the learner's domain). $\sum a(x,y) = a_1 \vee a_2 \vee \cdots \vee a_k$. If $a(x,y) = \varnothing$, then let $\sum a(x,y) = 1$. Discernibility function is defined as: $\Delta = \prod_{(x,y)\in U\times U} \sum a(x,y)$.

Theorem 1: The minimal disjunctive normal form of the discernibility function Δ corresponds to the all reduction set of S.

Definition 7. Reduction efficiency

The data volume of the information system before the reduction is defined as: $E_S = |C| * |U|$ and after the reduction is defined as: $E_S^{'} = |C^{'}| * |U|$. The reduction efficiency is: $E = 1 - E_S^{'} / E_S$.

4 Find the Key Personality Characteristic Attributes

Under the background of College English learning in Xi'an Jiaotong University, China, the concrete personality characteristic, learning strategies, etc., are defined as above, then finding the key personality characteristic attributes can be applied as following.

To obtain the reducts, the improved method is used to analyze ISLPC. Here, personality characteristic, defined as C, are the conditional attributes and learning strategies are the decision attributes. Once the reduced set is available, we order the attributes based on the value of SGF , defined in Section 3, and, at last, find the key personality attributes.

Since the huge volume of e-learners and high dimension attributes of personality characteristic, the traditional reduction methods are generally not suitable. This paper proposes a method that directly builds *core set* and *non-core set* and calculates the reducts based on the logical calculation. In the method, discernibility matrix[9][10], that costs huge space, can not be generated and, moreover, an optimal strategy is applied, in which, the attributes in *nocore* set can be absorbed in advance to reduce the value of calculation. In worst situation that the number of the attributes is the cardinality of C , the time complex is $O(N^2 * C)$.

Core is the set of the attributes only by which any two learners can be distinguished in the domain. It is defined as:

$$core = \{c \in C : \exists c, \text{ such that } \forall c^* \in C,\ c^* \neq c, \text{having } f(x_i, c^*) = f(x_j, c^*) \text{ and } f(x_i, c) \neq f(x_j, c)\}$$

$nocore$ set includes the attributes that are not in *core*, but can still be used to distiguish any two learners in the domain. We have:

$$nocore = \{a \in C : a \not\subset core, \text{having } f(x_i, a) \neq f(x_j, a)\} .$$

The following condition must met: $core \subseteq C$, $nocore \subseteq C$, $core \cap nocore = \varnothing$.

The following is the detailed description of the algorithm:

Input: Information system $S = (U, C \cup D, V, f)$, including the learners' personality characteristic.

Output: The reduct red and the set of key personality characteristic K.

Steps:

Step 1: Let $red = \varnothing$; $nocore = \varnothing$; $core = \varnothing$; flag = 0; $attr = \varnothing$;

Step 2: Compare subjects in the domain one by one, calculate *core* set and *nocore* set. The following is the detail:

```
For ( i = N; i > 0; i--)              //N is the number of learner subjects in U
  {For ( j = i-1; j >0; j--)
        {
if  f(i,d) ≠ f(j,d)          // d ∈ D ,  refer to definition 2, f(i,d) is
                                  //described in definition 3
  { for ( k = 1; k <= FN; FN++)      //FN is the cardinality of the
                                      //personality characteristic set C ,
                                     //refer to definition 1
    if  i[k] ≠ j[k]
       {  attr = attr ∪ i[k] ;  //record the names of the personality
                                 //characteristic attributes that have
                                 //unequal values
 if  ( attr ∩ core ≠ ∅ )
   { attr = ∅ ;  got to step 2 ; } // apply optimal
                                   //strategy, that is to say, if
                                   // attr and core have
                                  //common attributes, then
                                  //the attributes was absorbed
                                 //in advance and need not be
                                // compared continually.

else
flag++;   //flag marks the number of personality
          //characteristic attributes that have unequal
            //values
       }
  }
if flag>1 {  nocore = nocore ∪ attr ;}  // the attribute in attr
                                        //is not core
if flag = 1
  {  core = core ∪ attr ;     //the attribute in attr is core
   if  ( attr ∩ nocore ≠ ∅ )
       nocore = nocore \ attr ;
}
```

flag=0;
$attr = \varnothing$;
}
}

Step 3: $red = \min\{|\alpha|, \alpha \in core \times nocore\}$;

Step 4: Convert $S = (U, C \cup D, V, f)$ to $S' = (U, red \cup D, V, f)$;

Step 5: Calculate SGF;

Step 6: Order the SGF value from the large to the small, calculate the key personality characteristic set K.

According to the above algorithm, when comparing subject 1 and 2, we can obtain $core = \{a\}$; when comparing subject 3 and 4, first obtained $attr = \{a\}$ and then applied the optimal strategy. Since $attr \cap core \neq \varnothing$, we need not calculate attributes a, b continually. If we calculate continually, we will obtain {a, b} and according to the logic absorb principle, {a, b} will be absorbed to {a} ultimately. So we applied the strategy and cut down the compared attributes to the best advantage. The effect is prominent because there are high dimension attributes in ISLPC. Specially, we carefully investigated the data of the e-learners and drew the conclusion that the values of most attributes are equal among e-learners. Such situation can get the most out of the strategy and dramatically decrease the cost of comparing the attributes.

5 Experiments and Analysis

The above method is illustrated by an example as follows. More than 300 students in several colleges of Xi'an Jiaotong University, China, have used the personalized English e-Learning system to improve their English skills. We have collected 157 valid samples from these students. In the situation, personality characteristic of each sample have 28 dimensions and, according to the definition 7 in Section 3, the value of E_S is 4396. As showed in the following, after the above method processes the samples, the dimensions of key personality characteristic attributes can be decreased to below one-forth and the reduction rate E can mostly be about 50%. If the method will be applied to the realistic e-learning university, that there are thousands of students, the function will be more remarkable.

As described in definition 2, learning strategies set $D = \{mcs, afs, ffs, mfs, css\}$ includes multiple attributes. In order to simplify the calculation, according to the pedagogic theory, these five learning strategies can be separately implemented to speed the process of finding the optimal learning strategies. So, we decomposed $S = (U, C \cup D, V, f)$ into five different subsystems $\{S_1, S_2, S_3, S_4, S_5\}$, where $S_i = \{U, R_i, V, f\}$, $R_i = C \cup \{d_i\}, d_i$ $(1 \le i \le 5)$ represents the ith elements in the set $D = \{mcs, afs, ffs, mfs, css\}$.

We have applied the reduction algorithm described in Section 4 for $S_i = \{U, R_i, V, f\}$, $(1 \le i \le 5)$, respectively. The results are showed in table 1.

Table 1. Reducts for 5 learning strategies

Learning Strategy	*Reducts{Personality Characteristic Attribute Name}*
mcs	{C, E, H, I, M, N, O, Q2, Q4, GROUP1, GROUP3, GROUP4, MYYLLEVEL, XXXZLEVEL, XXCLLEVEL}
afs	{B, E, G, H, I, N, O, Q2, Q3, Q4, GROUP2, GROUP3, GYLEVEL, XXXZLEVEL, XXCLLEVEL}
ffs	{E, I, Q2, GROUP4, ZWXNLEVEL}
mfs	{A, C, G, H, N, O, Q2, Q3, Q4, GROUP1, GROUP3, GROUP6, MYYLLEVEL, ZWXNLEVEL, GYLEVEL}
css	{A, C, F, G, I, M, O, Q4, GROUP1, GROUP2, GROUP3, GROUP4, GROUP5, GYLEVEL, XXXZLEVEL, XXCLLEVEL}

We found that personality characteristic attributes included in each learning strategy varies significantly. No single characteristic attribute is related to all 5 strategies. Sensitity(I),apprehension(O), self-reliance(Q2), tension(Q4), group|individual lity(GROUP3) are attributes that affect 4 learning strategies. Therefore these attributes are key ones. Brilliance(B), excitement(F), systematic/random(GROUP5), spontaneity/thoughtfulness(GROUP6) are attributes that only affect one learning strategy. These personality characteristic are less important ones and can be eliminable if needed.

According to the definition 5 in Section 3, we can calculate the value of SGF for every attribute in each reduct and the detail is illustrated from table 2 to table 6. Then, it is clear, in table 2, that visual|auditory|experimental(GROUP1), shrewdness(N),

Table 2. The value of SGF for *mfs*

Characteristic Attributes (for *mfs*)	Attribute Name	SGF
Visual|Auditory|Experimental	GROUP1	0.1146
Shrewdness	N	0.0764
Social boldness	H	0.0701
Dependence on mother tongue	MYYLLEVEL	0.0637
Language learning conception	XXXZLEVEL	0.0510
Sensitivity	I	0.0382
Group|Individuality	GROUP3	0.0382
Apprehension	O	0.0255
Self-reliance	Q2	0.0255
Tension	Q4	0.0255
Emotional stability	C	0.0127
Dominance	E	0.0127
Learning strategy conception	XXCLLEVEL	0.0127
Imagination	M	0.0009
Analytical|Synthesis	GROUP4	0.0009

social boldness(H), dependence on mother tongue(MYYLLEVEL), language learning conception(XXXZLEVEL), sensitivity(I) and group|individuality(GROUP3) are key attributes for $mcs \in D$.

Similarly, ascribing conception(GYLEVEL), sensitivity(I), independence|dependence(GROUP2), social boldness(H), tension(Q4), persistence(G), self-reliance (Q2) are key attributes for $afs \in D$ in table 3.

Table 3. The value of SGF for *afs*

Characteristic Attributes (for *afs*)	Attribute Name	SGF
Ascribing conception	GYLEVEL	0.0701
Sensitivity	I	0.0510
Independence|Dependence	GROUP2	0.0510
Social boldness	H	0.0446
Tension	Q4	0.0446
Persistence	G	0.0382
Self-reliance	Q2	0.0318
Apprehension	O	0.0255
Self-discipline	Q3	0.0191
Learning strategy conception	XXCLLEVEL	0.0191
Language learning conception	XXXZLEVEL	0.0127
Brilliance	B	0.0008
Dominance	E	0.0008
Shrewdness	N	0.0008
Group|Individuality	GROUP3	0.0008

Dominance(E), analytical|synthesis(GROUP4), self-efficacy conception(ZWXNL EVEL), sensitivity(I) and self-reliance(Q2) are key attributes for $ffs \in D$ in table 4.

Table 4. The value of SGF for *ffs*

Characteristic Attributes (for *ffs*)	Attribute Name	SGF
Dominance	E	0.2803
Analytical|Synthesis	GROUP4	0.0828
Self-efficacy conception	ZWXNLEVEL	0.0764
Sensitivity	I	0.0318
Self-reliance	Q2	0.0318

Table 5. The value of SGF for *mfs*

Personality Characteristic (for *mfs*)	Attribute Name	SGF
Social boldness	H	0.0382
Apprehension	O	0.0318
Warmth	A	0.0255
Emotional Stability	C	0.0255
Tension	Q4	0.0255
Ascribing Conception	GYLEVEL	0.0255
Persistence	G	0.0127
Self-Reliance	Q2	0.0127
Self-discipline	Q3	0.0127
Visual|Auditory|Experimental	GROUP1	0.0127
Dependence on mother tongue	MYYLLEVEL	0.0127
Self-efficacy Conception	ZWXNLEVEL	0.0127
Shrewdness	N	0.0009
Group|Individuality	GROUP3	0.0009
spontaneity / thoughtfulness	GROUP6	0.0009

Social boldness(H) and Apprehension(O) are key attributes for $mfs \in D$ in table 5.

Sensitivity(I) and visual|auditory|experimental(GROUP1) are key attributes for $css \in D$ in table 6.

Table 6. The value of SGF for *css*

Personality Characteristic (for *css*)	Attribute Name	SGF
Sensitivity	I	0.0446
Visual|Auditory|Experimental	GROUP1	0.0382
Warmth	A	0.0255
Persistence	G	0.0255
Imagination	M	0.0255
Emotional stability	C	0.0127
Excitement	F	0.0127
Apprehension	O	0.0127
Tension	Q4	0.0127
Independence|Dependence	GROUP2	0.0127
Ascribing conception	GYLEVEL	0.0127
Language learning conception	XXXZLEVEL	0.0127
Learning strategy conception	XXCLLEVEL	0.0127
Group|Individuality	GROUP3	0.0007
Analytical|Systhesis	GROUP4	0.0007
Systematic|Random	GROUP5	0.0007

Now, we obtained the key personality characteristic attributes and during the development of personalized e-learning, these attributes have important influence to learning strategies and should be considered top-priority.

According to the definition 7 in Section 3, before using the reduction algorithm, the value of E_S for S_1 is 4396. After the reduction, the value of $E_S^{'}$ is 2355. The reducetion rates E for S_1, S_2 and S_4 are 46% respectively. The reduction rate E for S_3 is 82%. The reduction rate E for S_5 is 43%.

6 Conclusion

This paper investigated the problem of key personality attributes that influence the personalized learning strategies in e- learning and proposed an algorithm to effectively identify key personality attributes. The algorithm is based on the rough set theory and does not require any prior knowledge. An extensive experiment has been conducted in a major Chinese research university to validate the method and drew the initial results. In the future, the results will be used to instruct the construction of personalized e-learning system.

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