KNOWLEDGE DISCOVERY AND VISUALIZATION OF KIDNEY-RELATED PATTERN AND TREATMENT BASED ON ATTRIBUTE PARTIAL-ORDERED STRUCTURE DIAGRAM

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ABSTRACT. *Knowledge discovery and visualization of traditional Chinese medicine (TCM) has been a significant and challenging issue in the development of TCM. Aiming at knowledge discovery and visualization of kidney-related patterns and treatments, a method called 'attribute partial-ordered structure diagram' was adopted. Based on the mapping data of kidney-related patterns and treatments, the formal contexts were constructed, and thus the corresponding attribute partial-ordered structure diagrams were generated and analyzed. Through these diagrams, the mapping relations of kidney-related patterns and treatments are visualized clearly, and the analysis results are consistent with the theory of TCM and the study of other researchers.*
Keywords: Attribute partial-ordered structure diagram, Knowledge discovery and visualization, Traditional Chinese medicine, Kidney-related pattern and treatment

1. **Introduction.** As a complementary medical system to conventional Western medicine (CWM), traditional Chinese medicine (TCM) provides a unique theoretical and practical approach to the treatment of diseases over thousands of years. The holistic and systematic ideas of TCM are essentially different from the thinking modes based on Reductionism in CWM. With the development of modern science, people come to realize the limitations of Reductionism, and begin to lay more emphasis on the systematic thinking patterns. Countless TCM practices and theoretical researchers in thousands of years have accumulated a great deal of knowledge in the form of ancient books and literature. Confronted with such a vast volume of TCM knowledge, there is an urgent need to use these precious resources effectively and sufficiently by the techniques of knowledge discovery [1]. Knowledge discovery is defined as 'the non-trivial extraction of implicit, unknown, and potentially useful information from data', and this concept can be applied to data mining as well [2]. Retrieving knowledge hidden in text or data, and presenting the distilled knowledge such as associations, patterns to users in a concise form is the primary goal of knowledge discovery [3]. Attribute partial-ordered structure diagram (APOSD), which can extract knowledge from formal context and visualize the results in intelligible diagram, is a method of knowledge discovery proposed by Prof. Hong [4].

Over the past decade, APOSD has been widely employed in the field of knowledge discovery for TCM. Fan et al. [5] analyzed the prescription compatibility of Chinese medicine formulae based on APOSD. Li et al. [6] adopted APOSD to discover new knowledge of clinical diagnosis from the famous TCM doctors' experience about diabetes. Yan et al. [7] employed APOSD to explore acupoints selection rules and treatment philosophy for diabetes mellitus in acupuncture and moxibustion. Jing et al. [8] studied the formulations of decoctions in TCM. Song et al. [9] analyzed the knowledge structure of warm disease with APOSD.

These researches provide valuable experience on knowledge discovery of TCM and are suggestive of the effectiveness of APOSD in the field of TCM. In addition, disease of kidney-related patterns is quite common in clinical diagnosis and treatment, and revealing the rules of this kind of disease will be of great practical and academic value. Therefore, in this paper, APOSD is adopted to analyze the knowledge of kidney-related patterns and treatments.

This paper is organized as follows. Section 1 introduces the research background and the motivation of the study. Section 2 describes the theories of APOSD. Section 3 shows and discusses the results of knowledge discovery. Section 4 draws the conclusion of the study.

2. **Theory of Attribute Partial-Ordered Structure Diagram (APOSD).** APOSD is based on the principle of partial order in the theory of formal concept analysis (FCA) [10]. Formal context is the data basis of APOSD. A formal context $K = (U, M, I)$ consists of two sets $U = \{u1, u2, \ldots, un\}$ and $M = \{m1, m2, \ldots, mk\}$ and a relation I between U and M. The elements of U are called the objects and the elements of M are called the attributes of the context. The data shown in Table 1 is a classical example of formal context called 'biology and water'.

TABLE 1. Formal context of biology and water

	a1	a2	a3	a4	a5	a6	a7	a8	a9
o1	1	1					1		
o2	1	1					1	1	
o3	1	1	1				1	1	
o4	1		1				1	1	1
o5	1	1		1		1			
o6	1	1	1	1		1			
o7	1		1	1	1				
o8	1		1	1		1			

As shown in Table 1, the data in the first row is the set of attributes, while the data in the first column is the set of objects, and the number '1' in the intersection of object and attribute means the object has the attribute, or the attribute belongs to the object.

Similar to FCA, APOSD emphasizes cognitive ability and concentrates on the relation between different data sets. As shown in Figure 1, the principle of APOSD follows the basic principle of human being's cognition of classification of natural things. A concept is composed of attributes and objects. Attributes express the features of different objects, and the relations between the attributes show the relations between the concepts. Common attributes are the attributes commonly owned by different objects. They express the similarity of the objects, and they have more extent but less intent. While exclusive attributes express the individuality of the objects which distinct one object from the others, and they have more intent but less extent. In the cognition, people tend to put the objects with common attributes close together and to put the objects with exclusive attributes away from each other in order to classify different things (objects) [11].

The difference between FCA and APOSD is that FCA focuses on the generation and analysis of concept and concept lattice, while APOSD concentrates on the study of attributes' feature. Based on the formal context in Table 1, using the definition of attribute's feature [12] and the method of data processing [4], the APOSDs shown in Figure 2 can be generated.

As shown in Figure 2, APOSD can be presented in three styles: star [13], annular and tree. In APOSD, sequential structure visualization model is adopted. From top to bottom (tree style), or from inner to outer (star and annular style), the nodes of attributes
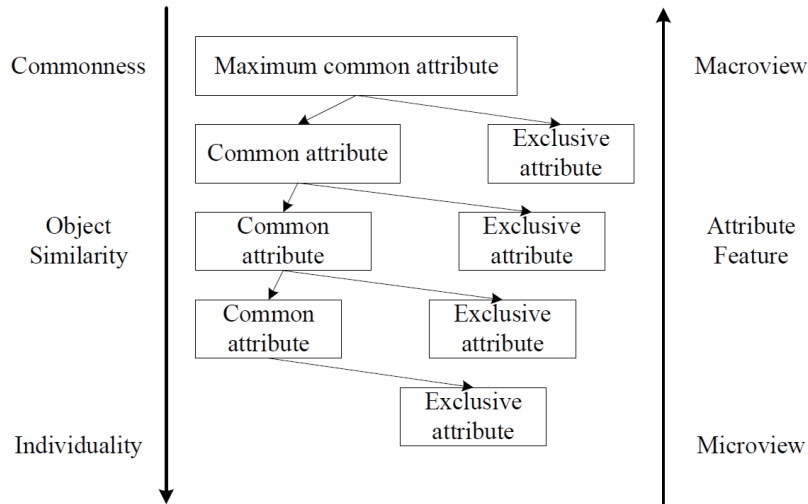
FIGURE 1. Principle of APOSD

a) Star style   b) Annular style   c) Tree style
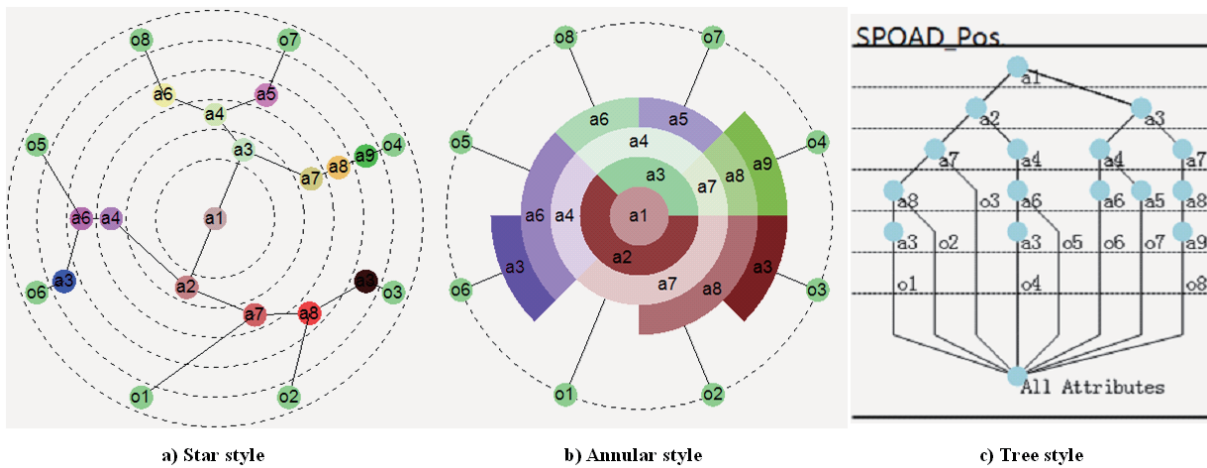
FIGURE 2. APOSD of biology and water

represent the constitution of the corresponding object and the layer each attribute node located in shows the universal degree of the attribute. The attribute located in the innermost (toppest) layer has the highest university (covering the most objects).

3. **Data Analysis.** In this section, the formal contexts of kidney-related patterns and treatments were constructed, and then the corresponding APOSDs were generated and analyzed. In addition, in this paper, only the annular style of APOSD is adopted.

3.1. **Construction of formal context.** The raw data of this paper's formal context is from a book written by Prof. Zhu [14]. Based on the data of kidney-related pattern and treatment in the book, the formal contexts shown in Table 2 and Table 3 were constructed.

The data given in Table 2 is the formal context of kidney-related patterns and syndrome elements, which contains the mapping relation between the two sets. There are 37 objects (kidney-related patterns) and 19 attributes (kidney-related syndrome elements) in this formal context:

Objects in Table 2: **o1**: kidney qi deficiency; **o2**: kidney deficiency and cold-dampness; **o3**: kidney deficiency and cold congealing; **o4**: kidney deficiency and cold-phlegm; **o5**: kidney deficiency and blood stasis; **o6**: kidney deficiency and cold-dampness obstruction; **o7**: dryness-heat and fluid depletion with kidney yin deficiency; **o8**: dryness-heat damaging to fluid with kidney qi yin deficiency; **o9**: dampness-heat in the kidney;

o10: dampness-heat in the kidney with water retention; **o11**: kidney qi insecurity; **o12**: kidney qi insecurity with exterior deficiency; **o13**: kidney qi insecurity with water-dampness; **o14**: debilitation of the life gate fire with kidney qi insecurity; **o15**: kidney yang deficiency with essential qi insecurity; **o16**: kidney deficiency with water flood; **o17**: kidney qi deficiency with water flood; **o18**: kidney yang deficiency with water flood; **o19**: fright and fear damaging to kidney; **o20**: kidney yang deficiency; **o21**: kidney yang qi deficiency; **o22**: kidney yang qi deficiency with bleeding; **o23**: kidney yang qi deficiency with essence depletion; **o24**: kidney yang qi deficiency with congealing cold and blood stasis; **o25**: kidney yang deficiency with internal retention of retained fluid; **o26**: devitalized kidney yang with blood deficiency and congealing cold; **o27**: kidney yin deficiency; **o28**: kidney yin deficiency with bleeding; **o29**: kidney yin deficiency

TABLE 2. Formal context of patterns and elements

	e1	e2	e3	e4	e5	e6	e7	e8	e9	e10	e11	e12	e13	e14	e15	e16	e17	e18	e19
o1	1	1																	
o2	1		1	1	1														
o3	1		1		1														
o4	1		1		1	1													
o5	1						1												
o6	1		1	1	1														
o7	1							1	1	1	1								
o8	1	1						1	1	1	1								
o9	1			1					1										
o10	1			1					1			1							
o11	1	1											1						
o12	1	1											1	1					
o13	1	1		1								1	1						
o14	1	1	1		1								1						
o15	1				1								1		1				
o16	1				1							1							
o17	1	1										1							
o18	1				1							1							
o19	1	1														1			
o20	1				1														
o21	1	1			1														
o22	1	1			1												1		
o23	1	1			1										1				
o24	1	1	1		1		1												
o25	1				1							1						1	
o26	1		1		1														1
o27	1							1											
o28	1							1									1		
o29	1							1	1					1					
o30	1							1							1				
o31	1							1		1	1								
o32	1							1	1										
o33	1														1				
o34	1				1			1											
o35	1	1						1											
o36	1	1			1			1							1				
o37	1																		

with insecurity of qi; **o30**: kidney yin deficiency with essence depletion; **o31**: kidney yin deficiency with fluid depletion and internal dryness; **o32**: kidney yin deficiency with heat; **o33**: kidney essence deficiency; **o34**: dual deficiency of kidney yin and yang; **o35**: dual deficiency of kidney qi and yin; **o36**: kidney yin-yang and essential-qi deficiency; **o37**: kidney deficiency.

Attributes in Table 2: **e1**: kidney; **e2**: qi deficiency; **e3**: cold; **e4**: dampness; **e5**: yang deficiency; **e6**: phlegm; **e7**: blood stasis; **e8**: yin deficiency; **e9**: heat; **e10**: dryness; **e11**: fluid depletion; **e12**: water retention; **e13**: insecurity of qi; **e14**: exterior; **e15**: essence deficiency; **e16**: heart spirit; **e17**: bleeding; **e18**: retained fluid; **e19**: blood deficiency.

TABLE 3. Formal context of patterns and treatments

	e1	t1	t2	t3	t4	t5	t6	t7	t8	t9	t10	t11	t12	t13	t14	t15	t16	t17	t18	t19	t20	t21
o1	1	1		1																		
o2	1	1	1		1	1																
o3	1	1	1		1																	
o4	1	1	1				1															
o5	1	1						1														
o6	1	1	1							1	1											
o7	1	1									1	1	1									
o8	1			1							1	1	1									
o9	1										1			1								
o10	1										1				1	1						
o11	1	1		1													1					
o12	1	1															1					
o13	1	1														1	1					
o14	1	1		1													1	1				
o15	1	1															1	1	1			
o16	1	1														1						
o17	1	1		1												1						
o18	1	1	1													1						
o19	1	1																			1	
o20	1	1	1																			
o21	1	1	1	1																		
o22	1	1	1	1																	1	
o23	1	1	1																1			
o24	1		1	1	1			1														
o25	1		1													1						
o26	1	1	1		1																	
o27	1	1											1									
o28	1	1											1								1	
o29	1	1											1				1					
o30	1	1											1						1			
o31	1	1										1	1									1
o32	1	1											1									
o33	1	1																	1			
o34	1	1	1										1									
o35	1	1		1									1									
o36	1	1	1										1					1	1			
o37	1	1																				

The data given in Table 3 is the formal context of kidney-related patterns and treatments, which contains the mapping relation between the two sets. There are 37 objects (kidney-related patterns) and 22 attributes (kidney and 21 kidney-related treatments) in this formal context:

Attributes in Table 3: **e1**: kidney; **t1**: tonify the kidney; **t2**: warm yang; **t3**: tonify qi; **t4**: dissipate cold; **t5**: dispel dampness; **t6**: resolve phlegm; **t7**: resolve stasis; **t8**: dry dampness; **t9**: free impediment; **t10**: clear heat; **t11**: engender fluid; **t12**: nourish yin; **t13**: drain dampness; **t14**: resolve dampness; **t15**: induce dieresis; **t16**: securing and astringing; **t17**: invigorate yang; **t18**: secure essence; **t19**: tranquilize; **t20**: stop bleeding; **t21**: moisten dryness.

The objects in Table 3 are identical with the ones in Table 2.

3.2. **Analysis of kidney-related patterns and syndrome elements.** Based on partial-ordered theory and the formal context in Table 2, the APOSD of kidney-related patterns and syndrome elements shown in Figure 3 was generated. In Figure 3, the hierarchical structure of mapping relations between kidney-related patterns and syndrome elements is expressed clearly. In Figure 3, the nodes located in the outermost layer are kidney-related patterns (objects), while the arcs in interior layers represent the syndrome elements (attributes) mapping to the patterns.

As shown in Figure 3, in the innermost layer, {e1 = kidney} is the most common element in kidney-related patterns. Under the cluster of {e1 = kidney}, in the second layer, the diagram is divided into three big arcs: {e5 = yang deficiency, e8 = yin deficiency, e2 = qi deficiency}, meaning that in kidney-related patterns, yang deficiency, yin deficiency and qi deficiency are the most common essence elements.
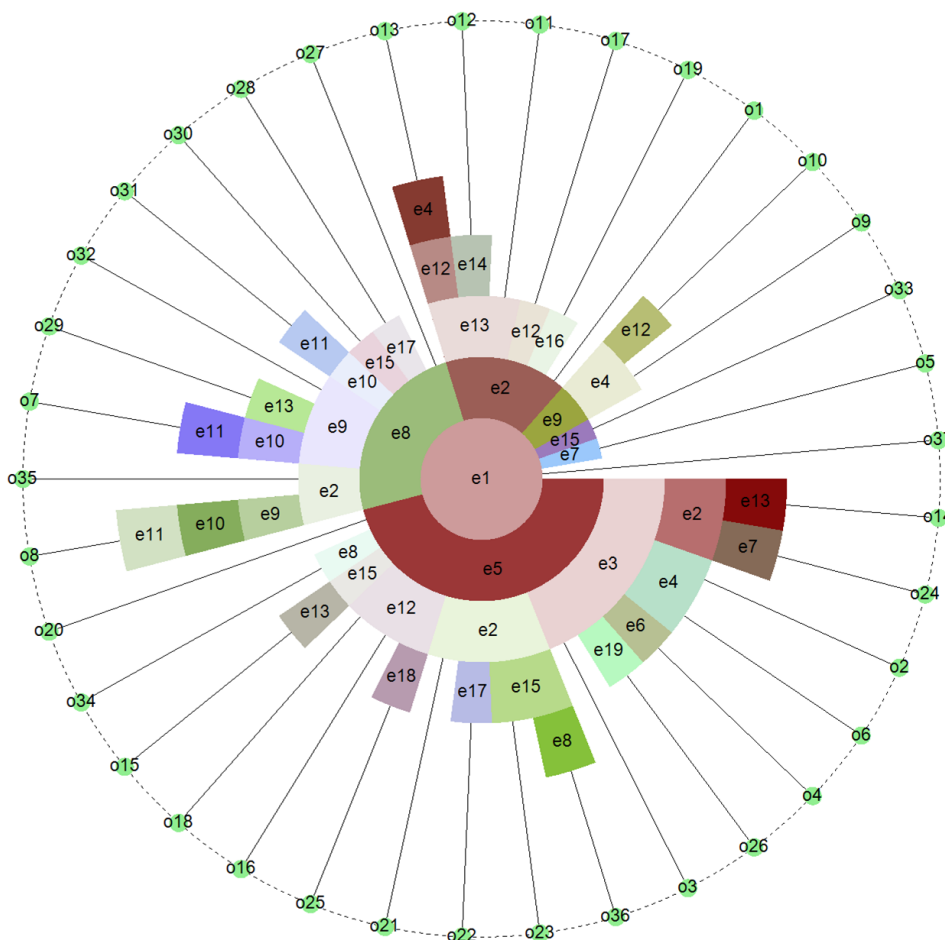
FIGURE 3. APOSD of patterns and elements

In the research of Prof. Kuang et al. [15], the results show that among the syndrome elements of essence related to kidney, the ones who have the highest frequency of occurrence are: qi deficiency, yin deficiency and yang deficiency, which are consistent with the results of APOSD.

Under the cluster of {e5 = yang deficiency}, in the third layer, {e2 = qi deficiency, e3 = cold, e12 = water retention} are three big clusters, indicating that in kidney-related patterns, yang deficiency is usually accompanied by qi deficiency, cold and water retention.

Under the cluster of {e8 = yin deficiency}, also in the third layer, {e9 = heat} is the biggest cluster, showing that in kidney-related patterns, yin deficiency often emerges with heat.

Under the cluster of {e2 = qi deficiency}, in the third layer, {e13 = insecurity of qi} is the biggest cluster, which means that in kidney-related patterns, qi deficiency often results in insecurity of qi.

3.3. **Analysis of kidney-related patterns and treatments.** Based on partial-ordered theory and the formal context in Table 3, the APOSD of kidney-related patterns and treatments shown in Figure 4 was generated. In Figure 4, the hierarchical structure of treatments in kidney-related patterns can be seen clearly. In Figure 4, the nodes located in the outermost layer are kidney-related patterns (objects), while the arcs in interior layers represent the treatments (attributes) corresponding to the patterns.

As shown in Figure 4, under the cluster of {e1 = kidney}, {t1 = tonify the kidney} is the biggest arc in the second layer, indicating that tonify the kidney is the most common treatment in kidney-related patterns.
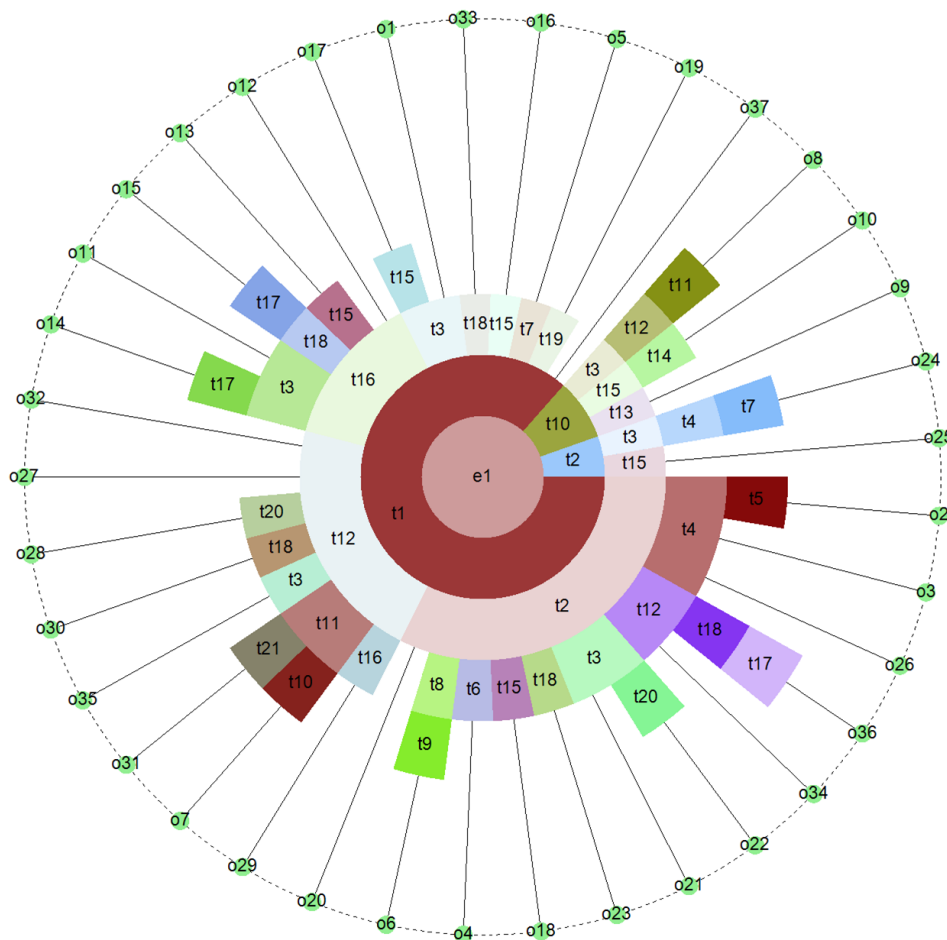
FIGURE 4. APOSD of patterns and treatments

Under the cluster of {t1 = tonify the kidney}, there are three big clusters in the third layer: {t2 = warm yang, t12 = nourish yin, t16 = securing and astringing}, among which '***warm yang***' is used for ***yang deficiency***, '***nourish yin***' is aimed at ***yin deficiency*** and '***securing and astringing***' is helpful to qi deficiency.

4. **Conclusions.** In this paper, based on the raw data of kidney-related patterns and treatments, the formal contexts were constructed; and then using the partial-ordered theory, the APOSDs were generated and analyzed. Through the diagrams and analysis, the knowledge of kidney-related patterns and treatments was expressed clearly; also the knowledge analysis results are satisfying. Therefore, APOSD is an effective method for knowledge discovery and visualization for TCM. Applying this method to other problems of TCM or other field except TCM should be a scientific research subject worthy of study.

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