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An Intuitive Dominant Test Algorithm of CP-nets Applied on Wireless Sensor Network

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Abstract: A wireless sensor network is of spatially distributed with autonomous sensors, just like a multi-Agent system with single Agent. Conditional Preference networks is a qualitative tool for representing ceteris paribus (all other things being equal) preference statements, it has been a research hotspot in artificial intelligence recently. But the algorithm and complexity of strong dominant test with respect to binary-valued structure CP-nets have not been solved, and few researchers address the application to other domain. In this paper, strong dominant test and application of CP-nets are studied in detail. Firstly, by constructing induced graph of CP-nets and studying its properties, we make a conclusion that the problem of strong dominant test on binary-valued CP-nets is single source shortest path problem essentially, so strong dominant test problem can be solved by improved Dijkstra's algorithm. Secondly, we apply the algorithm above mentioned to the completeness of wireless sensor network, and design a completeness judging algorithm based on strong dominant test. Thirdly, we apply the algorithm on wireless sensor network to solve routing problem. In the end, we point out some interesting work in the future. *Copyright © 2014 IFSA Publishing, S. L.*

Keywords: CP-Nets, WSN, Strong dominant test, Improved Dijkstra's algorithm, Completeness.

1. Introduction

A wireless sensor network (WSN) is of spatially distributed with autonomous and each single sensor, just like an Agent. A WSN can be used to monitor some parameters, such as temperature, humidity, pressure, etc. and transmit information cooperatively. Now, such networks are used in many industrial and domestic applications, such as data acquisition and control, intelligent home system, and so on.

The WSN is consisted of a few or several hundreds or even thousands, where each node is connected to another sensor or other sensors. Size and cost constraints on sensor nodes result in corresponding constraints on resources such as power supply, capacity, processing rate and communications baud rate. The topology of the WSN can be a polytree type network, or a simple star network or a sophisticated mesh network [1, 2].

The routing technology and dependent relation in WSN is very similar to conditional preference in artificial intelligence. When multiple Agents cooperate to solve the problem in the distributed artificial intelligence system, it is important for the Agents can understand each other's preferences and infer the degree of mutual interest which would be useful to make decision. The capability of dealing with the preference relation of Agents determines the space and time complexity, so it is very meaningful to research preference on the Agents community.

The main purpose of this paper is to determine the path covering problem in WSN, that is, for a large number of nodes with dependency relation, can we find a path which can connect all of them.

Preference research has attracted well-known scholars and has been appeared in top journal. Artificial Intelligence release a special issue which involves "Representing, Processing, and Learning Preferences: Theoretical and Practical Challenges" in May 2011. In this paper, we attribute the preference in three categories, namely, representation which includes model representation, logic representation and reasoning [6-8, 10-12], learning which researches how to learn and acquire individual preference through interaction [9-12], and aggregation which studies how to achieve a collective decision-making by aggregating the preference of multiple Agents [13-17].

Among the study of three aspects of preferences, preference representation is the basic work and most of the models are based on the CP-nets [3–9]. But some basic problems of CP-nets have not been resolved. One is the strong dominant test algorithm and its complexity are not resolved, and as an open question to be proposed in the literature [3].

In this paper, we focus on the strong dominance test and its application on wireless sensor networks. Section 1 proposes the main and existing problems. Section 2 gives syntax, semantics and instance of CP-nets. Section 3 studies the dominant test algorithm for an arbitrary binary-valued of CP-nets with Dijkstra's algorithm. Section 4 applies the completeness of CP-nets on WSN by using the algorithm in section 3. And in the ending section raises up conclusions and the future work.

This paper has two innovation ideas. (1) We study of CP-nets based on the property of induced graph and point out the nature of the strong dominant test on CP-nets is to determine the shortest path between any two vertices in the CP-nets induced graph. And we solve the strong dominant test and its time complexity of binary-valued CP-nets by taking advantage of the improved Dijkstra's algorithm, that is, a very intuitive way is given to solve an open problem in literature [1]; (2) We apply the algorithm above mentioned on the determination the completeness of CP-nets on wireless sensor networks.

2. CP-nets

2.1. Preference

Let $o \in \Omega$ is an outcome in decision space, which represents a configuration or combination. If there exist two outcome o and $o' \in \Omega$, which satisfy the ceteris paribus semantics, that is one attribute being different and all else attributes being equal, o and o' is called swappable relation.

If X_i is dependent on X_j or X_j is dependent on X_i, it is called dependent relation between X_j and X_i. If the preference of Agent on X_i is dependent on X_j, X_j is called father of X_i and X_i is called son of X_j. To be sure, the son and the father are both not the only one to the other.

Definition 1.

1) Let $\geq$ be a binary relation in decision space Ω, if $\geq$ is:

-*reflexive*, if $\forall o \in \Omega$, $o \geq o$

-*antisymmetric*, if $\forall o, o' \in \Omega$, $o \geq o' \wedge o' \geq o \rightarrow o = o'$

-*transitive*, if $\forall o, o', o'' \in \Omega$, $o \geq o' \wedge o' \geq o'' \rightarrow o \geq o''$

$\geq$ is called a partial order on Ω.

2) if $\forall$o, o' $\in\Omega$, o$\ngeq$o' and o' $\ngeq$o, o and o' is called incomparable. If there exists incomparable relation on Ω, then $\geq$ is called incompletely.

3) if $\forall o$, $o' \in \Omega$, $o \geq o'$ and $o' \geq o$, it is called indifferent.

2.2. CP-nets

Definition 2. A conditional preference table of X_i is a ranking of agent for $Dom(X_i)$ when the father of X_i is different. $CPT(X_i)$, that is conditional preference table of X_i, is constructed by the preference ranking of X_i value.

Definition 3. A CP-net $N = \langle V, CE \rangle$ is a directed graph, in which $V = \{X_1, X_2, ..., X_n\}$ is the set of vertices and $CE = \{(X_j, X_i) \mid X_j \in Pare(X_i), X_i \in V\}$ is the set of directed edges. The directed edge is dependent relation between X_i and X_j. For an arbitrary vertex X_i, there connects a $CPT(X_i)$.

2.3. Semantics of CP-nets

CP-nets follow ceteris paribus (all else being equal) semantic, that is, for an arbitrary outcome $o \in \Omega$, which value is different from another on the other same attributes. With ceteris paribus syntax, it is easy and quick to give which one is better than the other because the swappable outcome is different in only one attribute in intrinsic quality. For example, if there are two computers will be chosen and they only have one different configuration such as CPU with Intel and AMD, it is as easy as a pie when we choose one computer.

Example 1. Fig. 1 illustrates a CP-net that expresses Bob's preferences for evening dress. It consists of three variables C, S, and T, standing for the coat, shirt and tie, respectively. Bob unconditionally prefers black to white as a color for both the coat and the shirt, while Bob's preference between the blue and white tie is conditioned on the combination of coat and shirt: if they have the same color, then a white tie will make he too colorless, thus Bob prefers a blue tie. Otherwise, if the coat and the shirt are of different colors, then a blue tie will probably make him too frumpy, thus Bob prefers a white tie.

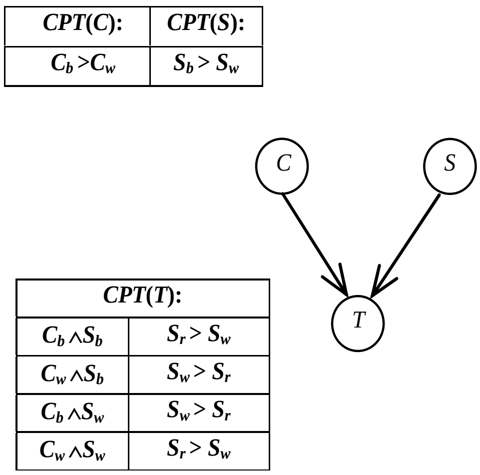

Fig. 1. The CP-net of evening dress.

For the example of CP-net N = <V, CE > is showed in Fig. 1 is $V = \{C, S, T\}$,Dom (C) =$\{C_b, C_w\}$,Dom (S) = $\{S_b, S_w\}$,Dom (S) =$\{T_r, T_w\}$; CE = {<C, T>, <S, T>}.

Fig. 2 shows the corresponding preference graph.

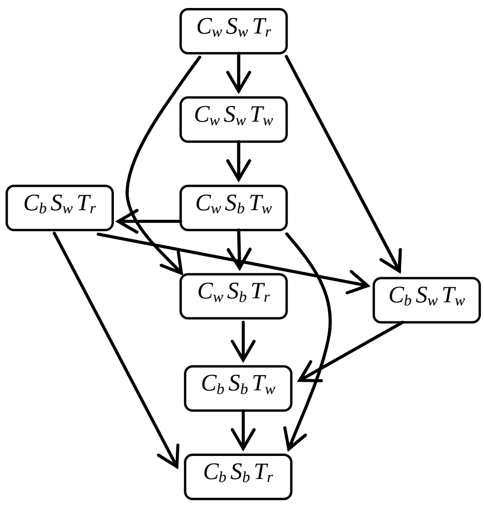

Fig 2. Induced graph of the CP-net in Fig. 1.

Theorem 1. For two swappable outcome o and o' in CP-nets N, the preference on them can be determined in O(n).

3. Strong Dominant Test on CP-nets

CP-nets can show the preference of Agent on some attributes. With some operations are defined on following, CP-nets will play a role of preference described language and can compare the outcome in the decision space. Among these operations, strong dominant test is the most basics which can compare the dominant relation between two outcomes.

3.1. Induced Graph of CP-nets

From theorem 1, we can get which is preferred between tow swappable outcomes quickly. The following discuss how to determine which is preferred between the arbitrary outcomes. The concept of induced graph of CP-nets and strong dominant test is given.

Definition 4. For a CP-net N = <V, CE >, $G = \langle \Omega, IE \rangle$ is the induced graph of N and in which, Ω is described as definition 1 and IE is the directed edge set constituted by swappable outcome. It should be pointed out that the preference of end vertex is preferred to the start vertex.

To intuitive understanding, this article discusses the attributes of CP-nets is binary. Or can be regarded as a Boolean variable which either attribute is true, or is false.

3.2. Strong Dominant Test

Definition 5. G = <Ω,IE > is induced graph of CP-nets N, for o, $o' \in \Omega$, if there exists a path from o' to o in G, it is called o is strong dominant to o', namely, $N \vDash o > o'$. The test of true or false of $N \vDash o > o'$ is called strong dominant test.

Theorem 2. It is strict dominant between two outcomes which are swappable relation.

Proof: Because the relation between the two outcomes which are flipping relation, namely only one feature is different. This includes two conditions. One is the first feature which has no parents is different, it can be got by CPT immediately. The other is not the first feature is different, it can be got by its parents.

Strong dominant test is an important operation on CP-nets. If $N \vDash o > o'$, it means o is preferred to o', namely, it exists a flip sequence which connects o and o' in CP-nets induced graph. Literature 1 gives some techniques like as Suffix Fixing, Least-Variable Flipping, Forward Pruning to determine whether $N \vDash o > o'$. The manners above mentioned are not easy, but they can get the strong dominant test in the Table 1 and does not work to on CP-nets with special structure.

Table 1. The complexity of strong dominant test on binary-valued CP-nets.

Structure of CP-nets	Complexity
Tree	$O(n^2)$
Polytree	$O(2^{2k} n^{2k+3})$
Single-connected DAG	NP-complete
δ-connected DAG	NP-complete
Arbitrary DAG	?

The following put our hands to the intrinsic of strong dominant test, namely, the shortest paths among vertices, to solve the strong dominant test on any arbitrary CP-nets.

3.3. Strong Dominant Algorithm Based on Shortest Path

Theorem 3. For $\forall o, o' \in \Omega$, if $N \vDash o > o'$, there may have zero, one path and multiple paths form o to o', which corresponding to incomparable relation, flip relation and multiple flips relation respectively.

Proof. If $o \not> o'$ and $o' \not> o$, it means that o is incomparable with o', namely, the CP-nets cannot express which is better between o and o' ,in this case, there is no any path from o to o'; If o and o' is flip relation, there exists one path from o to o'; If o and o' is not incomparable relation and flip relation, it may exists more than one path, and for example in Fig. 2, it need flip two times, namely, it has multiple paths from o_1 to o_5.

Definition 6. $G = <\Omega, IE>$ is the induced graph of the CP-net N. For a pair of outcome $o, o' \in \Omega$, Distance(o, o') indicates the shortest path from o to o'. If there does not exist any path from o to o', Distance(o, o') = ∞.

Corollary 1. $\forall o, o' \in \Omega$, if o and o' is incomparable, Distance(o, o') = ∞; if o and o' is swappable, Distance(o, o') = 1.

From corollary 1, we know that if we can find a path from o to o', $o > o'$ holds up.

Theorem 4. If $1 \le$ Distance(o, o') $< \infty$ exists in the induced graph of CP-nets, $o > o'$ holds up.

The intuitive meaning of theorem 4 can be considered as that, if there exists a path which distance is limited, $o > o'$ holds up; if there not exists a path or the distance is unlimited, $o > o'$ does not hold up.

In the induced graph of the CP-nets, if the shortest path from o to o' is Distance(o, o') = k , $o > o'$ holds up, and the time of swap from o to o' is k . It follows that the problem of strong dominant test can be transferred to question of shortest paths. Therefore, the improved Dijkstra's algorithm can be used to solve the dominance problem.

Dijkstra's algorithm, conceived by computer scientist Edsger Dijkstra in 1956 and published in 1959, is a graph search algorithm that solves the single-source shortest path problem for a graph with non-negative edge path costs, producing a shortest path tree. This algorithm is often used in routing and as a subroutine in other graph algorithms.

The main idea is as follows. For a given source vertex V in the induced graph of CP-nets, the algorithm seeks the shortest path between that source vertex and each other vertex. The algorithm for looking for the shortest path from a single vertex to a single destination vertex will stop by once the shortest path to the destination vertex has been determined.

The improved Dijkstra's algorithm can described as following (Fig. 3).

Input : adjacent matrix A[m][m] of $G = <\Omega, IE>$, in which $m = 2^n$
Output : reachable matrix B[m][m]

Int A[m][m]
For i =1 to m ***Do***
  For j =1 to m ***Do***
    If A[i][j] $\neq \infty$,A[j][k] $\neq \infty$
    then A[i][k] = A[i][j] +A[j][k]
    If A[i][j'] +A[j'][k] < A[i][j] +A[j][k]
    Then A[i][k] = A[i][j'] +A[j'][k]
  End For
End For
B[m][m]= A[m][m]

Fig. 3. Dijkstra's algorithm for strong dominant test.

Example 2. How to get the shortest path from o_1 to the other vertices in $G = <\Omega, IE>$ with Dijkstra's algorithm. In this example, $\Omega = \{o_1, o_2, o_3, o_4, o_5, o_6, o_7, o_8\}$, o_1 = "$J_w P_w S_w$", o_2 = "$J_w P_w S_r$", o_3 = "$J_w P_b S_r$", o_4 = "$J_w P_b S_w$", o_5 = "$J_b P_b S_w$", o_6 = "$J_b P_b S_r$", o_7 = "$J_b P_w S_r$", o_8 = "$J_b P_w S_w$".

The edges set of induced graph of CP-nets $IE = \{<o_1, o_2>, <o_2, o_3>, <o_3, o_4>, <o_4, o_5>, <o_5, o_6>, <o_1, o_4>, <o_1, o_8>, <o_2, o_7>, <o_3, o_6>, <o_7, o_6>, <o_7, o_8>, <o_8, o_5>\}$.Then, adjacent matrix is

$$A=\begin{bmatrix} 0 & 1 & \infty & 1 & \infty & \infty & \infty & 1 \\ \infty & 0 & 1 & \infty & \infty & \infty & 1 & \infty \\ \infty & \infty & 0 & 1 & \infty & 1 & \infty & \infty \\ \infty & \infty & \infty & 0 & 1 & \infty & \infty & \infty \\ \infty & \infty & \infty & \infty & 0 & 1 & \infty & \infty \\ \infty & \infty & \infty & \infty & \infty & 0 & 1 & \infty \\ \infty & \infty & \infty & \infty & \infty & \infty & 0 & 1 \\ \infty & \infty & \infty & \infty & 1 & \infty & \infty & 0 \end{bmatrix}$$

With Dijkstra's algorithm, then reachable matrix is

$$B=\begin{bmatrix} 0 & 1 & 2 & 1 & 2 & 3 & 2 & 1 \\ \infty & 0 & 1 & 2 & 3 & 2 & 1 & 2 \\ \infty & \infty & 0 & 1 & 2 & 1 & \infty & \infty \\ \infty & \infty & \infty & 0 & 1 & 2 & \infty & \infty \\ \infty & \infty & \infty & \infty & 0 & 1 & 2 & \infty \\ \infty & \infty & \infty & \infty & \infty & 0 & 1 & 2 \\ \infty & \infty & \infty & \infty & \infty & \infty & 0 & 1 \\ \infty & \infty & \infty & \infty & 1 & \infty & \infty & 0 \end{bmatrix}$$

In this matrix, 0 is comparable outcome to itself. A natural number just like 1,2,or 3 is the path from one outcome to another outcome. ∞ is there no path from the vertex to any other vertex.

4. Application of Strong Dominant Test on WSN

There exist 2^n vertices in binary-valued CP-nets. Because of the anti-symmetric of strong dominant test, it can express the quantity of preference relation is 2n*(2n–1)/2 = 2n–1*(2n–1). But we do not know whether it can express every preference relation, that is, the completeness of preference relation. The following try to start from strong dominant algorithm to discuss the completeness problem of CP-nets.

4.1. Completeness of WSN

CP-nets are a language of preference representation. A nature problem is whether it can express all of the preference relation in the outcome space. This part applies the strong dominant algorithm to completeness test of CP-nets.

The main characteristics of a WSN include power consumption constraints for nodes using batteries or energy harvesting, ability to cope with node failures, mobility of nodes, communication failures, heterogeneity of nodes, scalability to large scale of employment, ability to withstand harsh environmental conditions, ease of use and etc. The dependency relation among sensors is just like the CP-nets among Agent [18, 19].

Every one single sensor has different preference on the characteristics, whether it can express all of them? For being understood easily, binary value WSN is introduced in the following.

Definition 7. The number of binary-valued WSN which can express is $2^{n-1}*(2^n-1)$, then it is called completeness.

From theorem 2, we know that a binary-valued acyclic WSN can express 2^n outcomes. The number of preference relation among those outcomes is $2^{n-1}*(2^n-1)$.

The quantity of a WSN can express is closely related with its structure. The structure is different, the number of preference relations it can express is also different.

Example 3. How to get the completeness of a binary-valued and three-vertices WSN which has set-structure, chain-structure and tree-structure respectively.

The example 2 in section 3.3 is a tree-structured CP-net is a tree-structured WSN. The quantity of element 1 in the reachable matrix B of its induced graph is 23, in other words, the quantity of strong dominant relation the CP-nets can express is 23. And the total number of comparable outcome is 8*7/2 = 28 in Fig. 2. We have get 23 strong dominant relations among the outcomes, the remaining 5 pairs relations is still not expressed, that is, it is not completeness of if the CP-nets is replaced by WSN.

The following, we discuss the completeness problem of the set-structure and chain-structure WSN (Fig. 4) based on the Dijkstra's algorithm to find some fundamental theory to analyze the completeness of arbitrary-structure WSN. The outcome is represented by, o_0 = " $a_0\ b_0\ c_0$",o_1 = " $a_0\ b_0\ c_1$",o_2 = " $a_0\ b_1\ c_0$",o_3 = " $a_0\ b_1\ c_1$",o_4 = " $a_1\ b_0\ c_0$",o_5 = " $a_1\ b_0\ c_1$",o_6 = " $a_1\ b_1\ c_0$",o_7 = " $a_1\ b_1\ c_1$".

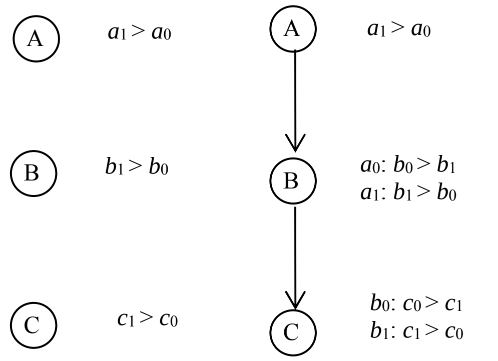

Fig. 4. Set-structure and chain-structure WSN.

1) Considering the set-structure WSN on the left of Fig. 4, the edges set of the induced graph is *IE*= {$\langle o_0, o_1\rangle$, $\langle o_0, o_2\rangle$, $\langle o_0, o_4\rangle$, $\langle o_1, o_3\rangle$, $\langle o_1, o_5\rangle$, $\langle o_2, o_3\rangle$, $\langle o_2, o_6\rangle$, $\langle o_3, o_7\rangle$, $\langle o_4, o_5\rangle$, $\langle o_4, o_6\rangle$, $\langle o_5, o_7\rangle$, $\langle o_6, o_7\rangle$}, and the adjacent matrix is

$$A=\begin{bmatrix} 0 & 1 & 1 & \infty & 1 & \infty & \infty & \infty \\ \infty & 0 & \infty & 1 & \infty & 1 & \infty & \infty \\ \infty & \infty & 0 & 1 & \infty & \infty & 1 & \infty \\ \infty & \infty & \infty & 0 & \infty & \infty & \infty & 1 \\ \infty & \infty & \infty & \infty & 0 & 1 & 1 & \infty \\ \infty & \infty & \infty & \infty & \infty & 0 & \infty & 1 \\ \infty & \infty & \infty & \infty & \infty & \infty & 0 & 1 \\ \infty & \infty & \infty & \infty & \infty & \infty & \infty & 0 \end{bmatrix}$$

And the reachable matrix is

$$B=\begin{bmatrix} 0 & 1 & 1 & 2 & 1 & 2 & 2 & 2 \\ \infty & 0 & \infty & 1 & \infty & 1 & 2 & 2 \\ \infty & \infty & 0 & 1 & \infty & \infty & 1 & 2 \\ \infty & \infty & \infty & 0 & \infty & \infty & \infty & 1 \\ \infty & \infty & \infty & \infty & 0 & 1 & 1 & 2 \\ \infty & \infty & \infty & \infty & \infty & 0 & \infty & 1 \\ \infty & \infty & \infty & \infty & \infty & \infty & 0 & 1 \\ \infty & \infty & \infty & \infty & \infty & \infty & \infty & 0 \end{bmatrix}$$

The number of ∞ is 8 and the number of limited numerals is 20 in the up diagonal matrix B. And the strong dominance relation number of the three-vertices binary-valued WSN can express is $8\times7/2 = 28$. So we can get the results as that there are 28–20 =8 pairs strong dominance relation cannot be expressed by the above mentioned set-structure WSN.

2) Considering the chain-structure WSN on the right of Fig. 3, the edges set of the induced graph is

$IE = \{<o_0, o_4>, <o_1, o_0>, <o_1, o_5>, <o_2, o_0>, <o_2, o_3>, <o_2, o_6>, <o_3, o_1>, <o_3, o_7>, <o_4, o_6>, <o_5, o_4>, <o_5, o_7>, <o_6, o_7>\}$ and the adjacent matrix is

$$A=\begin{bmatrix} 0 & 1 & \infty & 1 & \infty & 1 & \infty & \infty \\ \infty & 0 & 1 & \infty & \infty & \infty & \infty & \infty \\ \infty & \infty & 0 & 1 & \infty & \infty & \infty & 1 \\ \infty & \infty & \infty & 0 & 1 & \infty & \infty & \infty \\ \infty & \infty & \infty & \infty & 0 & 1 & \infty & \infty \\ \infty & \infty & \infty & \infty & \infty & \infty & 1 & \infty \\ \infty & \infty & \infty & \infty & \infty & \infty & 0 & \infty \\ \infty & \infty & \infty & \infty & 1 & \infty & 1 & 0 \end{bmatrix}$$

And the reachable matrix with Dijkstra's algorithm is

$$B=\begin{bmatrix} 0 & 1 & 2 & 1 & 2 & 1 & 2 & 3 \\ \infty & 0 & 1 & 2 & 2 & 4 & 3 & 2 \\ \infty & \infty & 0 & 1 & 2 & 3 & 2 & 1 \\ \infty & \infty & \infty & 0 & 1 & 2 & 3 & \infty \\ \infty & \infty & \infty & \infty & 0 & 1 & 2 & \infty \\ \infty & \infty & \infty & \infty & \infty & 0 & 1 & \infty \\ \infty & \infty & \infty & \infty & \infty & \infty & 0 & \infty \\ \infty & \infty & \infty & \infty & 1 & 2 & 1 & 0 \end{bmatrix}$$

The number of ∞ pairs is 1 and the number of limited numerals is 27 in the matrix B. So there is $28-27=1$ pairs strong dominance relation cannot be expressed by the above mentioned chain-structure WSN.

4.2. Completeness Theorem of WSN

Theorem 5. WSN is complete, if and only if the WSN export diagrams have the shortest path between two arbitrary vertices.

Proof. If the preference relation what the WSN can express is complete, that is, the preference relation what the arbitrary-vertices or arbitrary-structure WSN can express is $2^{n-1}*(2^n-1)$. But from example 2 and section 4.1, we can know what the arbitrary structure WSN can express is different. And the pairs in reachable matrix with Dijkstra's algorithm is less than $2^{n-1}*(2^n-1)$, which means that is not complete for the strong dominance relation on the WSN.

The above mentioned WSN is not complete. But the following example is complete.

Example 4. If V $=\{A, B, C\}$, $CE=\{AC, BC, AC\}$, $CPT(A)=\{a_1>a_0\}$, $CPT(B)=\{a_1 : b_1 > b_0, a_0 : b_1 > b_0\}$, $CPT(C)=\{a_0\ b_0 : c_1 > c_0, a_0\ b_1 : c_1 > c_0, a_1\ b_0 : c_1 > c_0, a_1\ b_1 : c_1 > c_0\}$, then from theorem 4, the WSN is complete.

Corollary 2. (Completeness theorem by improved Dijkstra's algorithm) : For the adjacency matrix of WSN, if the reachable matrix not exist pairs of ∞ after Dijkstra's algorithm operation, the WSN is complete.

The algorithm about Corollary 2 is showed by the following Fig. 5.

Completeness **theorem of Dijkstra's Algorithm**

Input : WSN N.
Output : Whether the WSN is complete.

With theorem 1 and 2, gain an adjacent matrix A[m][m]
With algorithm 1, gain a reachable matrix $B[m][m]$
For arbitrary p and q which are not equal,
If ($B[p][q]=\infty$ *and* $B[q][p]=\infty$) ***Then*** Printf ("N is not complete")
If ($B[p][q]\neq\infty$ *and* $B[q][p]=\infty$) ***Then*** Printf ("N is complete ")

Fig. 5. Completeness theorem of Dijkstra's Algorithm.

5. Conclusions and Future Work

In this paper, the strong dominant test on CP-nets comes down to the shortest path problem, so the theorem and algorithm can be given in intuitive method. In addition, it is applied in the completeness of WSN, and the theorem and algorithm is proposed. The relation of strong dominant test and completeness judgment is given soon afterwards.

Two further research directions of CP-nets and its application is still worth studying. One is to understand the expressive power of CP-nets better, specially: what sort of partial orderings are and are not representable by CP-nets; and among orderings representable by CP-nets, which ones are can only be represented by a cyclic network, just like as how to express WSN. The other is to research some other mathematical properties of the CP-nets, such as consistency, satisfiability and application on WSN.

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