Journal of Advanced Computing Research Vol. 1, Issue 1 (2016) 57-59

Dijkstra's Shortest-Path Algorithm Application

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***Abstract*—One of famous topic in study of graph theory is shortest path problem because of its wide application field, outspreading from operational research to the disciplines of computer science, topography, programmed control, and stream of traffic. Researchers in the relevant field have presented many algorithms according to its existing application, but most of the algorithms are only enhancements based on Dijkstra algorithm. The objectives of this research are to improve the efficiency of the shortest path algorithms and to enhance the kinds of it. This paper provided an upgraded calculation method of shortest path using cellular automata model, which is designed to examine the shortest path from one node to another node. This evaluation should be particularly useful to researchers and experts in management science, operations research, transportation, and Geographic Information Systems.**

***Keywords:* Dijkstra, Shortest path algorithm, Graph**

I. Introduction

Dijkstra's algorithm is applied to automatically find directions between physical locations, such as driving directions on websites like MapQuest or Google Maps. In a networking or telecommunication applications, Dijkstra's algorithm has been used for solving the min-delay path problem (which is the shortest path problem). For example in data network routing, the goal is to find the path for data packets to go through a switching network with minimal delay[1]. In the process of production, organization and management, we need to solve many shortest path problems. For instance, in the process of production, to complete production responsibilities speedily and with efficiency, we should discover the shortest path to complete every production task; in the process of organization, to make huge advantages with minimal rate, we should develop rational strategies, in the existing transport network, to transport large amount of properties with minimal expenses, we should arrange for rational transport path. All these questions can be summed up as the "shortest path problem". Researchers in appropriate field have presented many algorithms according to shortest path real application, but most of the algorithms are only advances based on Dijkstra algorithm [2]. Five aspects on shortest path are mostly being focused while doing the research which are: first, loss-algorithm, for example, limiting the search range, second, optimizing operation structure and increasing algorithm effectiveness algorithm to provide service for parallel computing according to specific network structure, third, limiting network characteristics, fourth, adopting parallel and fifth, adopting Stratford topological view to supply shortest path with part of instantiation coding [3].

A cellular automata (CA) is a dynamic system. According to certain native rules, it is well-defined on the cellular space relating of cellular with discrete and narrow states. It will change on the discrete time dimension. The traditional method different from the modelling method of cellular automata. The latter is based on macro-data, with which complex problems are extremely distracted on the origin of hypothesis and are explained through mathematical equation. However, the previous is a kind of study method begin from the lowermost to the highest, with which the macroscopic result is generated by the sum of microcosmic individuals which are constructed and abstracted from the research article [4]

Additionally, discrete time, discrete three-dimensional, limited and discrete state, standard CA highlights parallelism, spatial area, homogeneity, fleeting and high measurements. Cellular Automata has been connected to the fields of environment, software engineering, human science, science, topography, surroundings, transportation examines, and numerous different controls with the improvement of PC innovation. The attributes of parallelism and high measurement make CA more magnificent in the examination of system and way. In this present reality, there are two sorts of systems. One is undetectable, and the other is substantial. More system issues are broke down and tackled by CA hypothesis.

In the invisible system, numerous mind confusing issues, for example, routing policy [5], the entire conduct of hubs in PC system [6] and its number of nodes accelerating increasing with its growth condition of complex network [7] have been successfully analysed and solved with CA theory. [8] designed a shortest path algorithm based on cellular automata drawn-out model in 2004, by defining cellular evolution rules and cellular state to control the growth of cellular state, they got the shortest path of graph. But only the node order of receiving the shortest path could be obtained by the algorithm, and there is still no way to get the shortest path value. In 2010, [9] recommended an value-added algorithm, in which he added extra recording information of cellular state income.

Based on the above revisions, the existing algorithms had been improved through previous research. Cell state set is stable with mix of develop states and reproducing. In order to enhance parallelism; progression rules of existing algorithm should be improved.

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II. Introductions of Shortest Path Algorithm Based on CA

A. Mathematical definition of Cellular Automata

Cellular Automata (CA) consists of six parts which are cellular, cellular space, cellular state, neighbours, time and rules. Standard cellular automata could be well-defined as a quaternion by the mathematical symbols, A: A ¼ (Ld, S, N, f), where A represents a cellular automata system, d is a positive integer and L stands for the cellular space, it representing the dimension of cellular space; S is finite and discrete cellular states set; N means a combination of all the neighbour cellular together with the centre cellular f is local transformation function in cellular space, namely evolution rules.

B. Definition of shortest path algorithm based on CA

At the point when the particular issues are changed into weighted diagram to locate the most narrow way, every one of the hubs are characterized as a cell set, with each hub as a cell. The hub associated with the cell with edges would be characterized as its neighbors; time progress standard is considered as the smallest surplus weight and is reformed with the transformative [8]

III. Shortest Path Algorithm Based on CA Proposed by Wu Xiaojun

There are four states of evolution rules for the algorithm cellular state which are null (S_N), breeding (S_B), growth (S_G), and mature (S_M). Ri is the surplus weight of cellular i and minr is the smallest surplus weight at current step. The current state of centre cellular is as follows:

- S_M state, showing that the cell is in full grown state, has found the most limited way, and won't be changed at next stride.
- S_B state, showing that the cell is in rearing state, has establish the briefest way, and will be transformed into S_M state at next stride.
- S_N state, implying that the cell is in invalid state. The condition of its neighbor cell would be checked right now. On the off chance that there is any neighbor cell j in the S_B state, the inside cell i will be converted into S_G state at next stride. In the meanwhile, the surplus weight of center cellular i is corrected as follows:

  Ri ¼ distance(i,j)

where distance (i, j) means the edge weight between the node i to j.

- S_G state showing that the cell is in development state. On the off chance that inside cell i satisfy the state of Ri¼ minr, it will be transformed into S_B state at next stride.

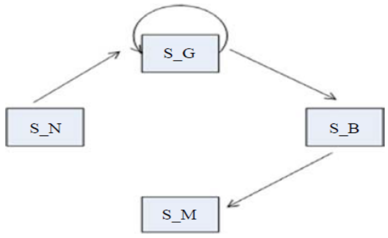

Figure 1. Cellular state turnover diagram of the Wu Xiaojun's shortest path algorithm

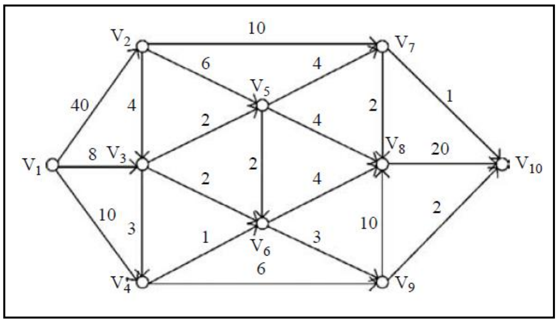

Figure 2. Weighted graph

Among many algorithms for the shortest path problem, Dijkstra's algorithm described below is most important.

Dijkstra's Algorithm

Step 0: Set $U := V$. Set $\pi(s) := 0, \pi(v) := +\infty (v \in V \backslash \{s\})$.

Step 1: Set $W := \arg\min\{\pi(v) \mid v \in U\}$ and $X := U \backslash W$.

Step 2: If $X = \emptyset$, then stop; for $v \in V, \pi(v)$ is the shortest path length from s to v.

Step 3: For $v \in X$, set

$$\pi(v) := \min\left[\pi(v), \min\{\pi(u) + \ell(u,v) \mid (u,v) \in E,\ u \in W\}\right].$$

Set $U := X$. Go to Step 1.

Figure 3. Step to find Dijkstra shortest path algorithm

Table 1 Evolution table of cellular state of Wu Xiajun

Step	V_1	V_2	V_3	V_4	V_5	V_6	V_7	V_8	V_9	V_{10}	Minr
0	S_B	S_N	S_N	S_N	S_N	S_N	S_N	S_N	S_N	S_N	0
1	S_M	S_G/40	S_G/8	S_G/10	S_N	S_N	S_N	S_N	S_N	S_N	8
2	S_M	S_G/32	S_B	S_G/2	S_N	S_N	S_N	S_N	S_N	S_N	0
3	S_M	S_G/4	S_M	S_G/2	S_G/2	S_G/2	S_N	S_N	S_N	S_N	2
4	S_M	S_G/2	S_M	S_B	S_B	S_B	S_N	S_N	S_N	S_N	0
5	S_M	S_G/2	S_M	S_M	S_M	S_M	S_G/4	S_G/4	S_G/3	S_N	2
6	S_M	S_B	S_M	S_M	S_M	S_M	S_G/2	S_G/2	S_G/1	S_N	0
7	S_M	S_M	S_M	S_M	S_M	S_M	S_G/2	S_G/2	S_G/1	S_N	1
8	S_M	S_M	S_M	S_M	S_M	S_M	S_G/1	S_G/1	S_B	S_N	0
9	S_M	S_M	S_M	S_M	S_M	S_M	S_G/1	S_G/1	S_M	S_G/2	1
10	S_M	S_M	S_M	S_M	S_M	S_M	S_B	S_B	S_M	S_G/1	0
11	S_M	S_M	S_M	S_M	S_M	S_M	S_M	S_M	S_M	S_G/1	1
12	S_M	S_M		S_M	S_M	S_M	S_M	S_M	S_M	S_B	0
						S_M					

IV. Literature Review

This section exposed some of the works that have been carried out by other researcher in the application of Dijkstra Shortest Path Algorithm. Dijkstra's algorithm is a surely understood calculation for the single-source most brief way issue in a coordinated chart with nonnegative edge length. Dijkstra's algorithm was discussed from the perspective of discrete arched investigation, where the idea of discrete convexity called L-convexity assumes a focal part. The dual of the linear programming (LP) formulation of the shortest path problem was observed first before it can be seen as a special case of L-concave function maximization [10]. According to [11], Dijkstra's algorithm summed up for finding most limited ways in digraphs with non-negative necessary edge lengths. Rather than naming singular vertices, label sub graphs which segment the given chart. As an application of VLSI routing problem, it is necessary to find lots of shortest paths in partial grid graphs with thousands or billions of apexes. The research done by [12] in article of Micro Crack Detection With Dijkstra’s Shortest Path Algorithm, shortest path algorithm had been used to spot micro cracks in situations where the cracks are bounded by plastic distortions and where a discrimination between plastics and cracks warps is tough. Then the crack paths are resolute by Dijkstra’s algorithm through the dimmest parts of the crack clusters as lengthiest shortest paths.

Next, paper [13] shows a study conducted about Dijkstra’s algorithm for solving the shortest path problem on networks under intuitionistic fuzzy environment. An empirical procedure for solving the SPP has been established, which aim to exploit acceptance for inaccuracy, partial truth, uncertainty and to achieve robustness, controllability, and low rate solution equivalent to the minimum-cost path or the shortest path. The shortest path problem occurs in variety of ranges. A well-known shortest path algorithm is Dijkstra's, also entitled as "label algorithm" [3]. There are a wide range of operations that should be possible on charts to finding a base way. Generally, methods such as Prim's algorithm and Kruskal's algorithm discover the most effective way to solve the minimum path problem. Dijkstra's Algorithm had been used to solve this problem successfully and the result with GA algorithm was compared to find the best solution [14]. Furthermore, Dijkstra’s algorithm is introduced and applied to assist the problem of optimization plan of the cutting edges of the twist drill based on Dijkstra’s algorithm [15]. Dijkstra shortest path is also applied in AGV control. In the process of searching, Dijkstra's algorithm as well as try and error method are respectively used to get the optimal or estimated optimal path, and finally gets a whole plan by comparing the outcome of two algorithms [16]. Besides, Dijkstra shortest path method is also used in an estimation of a 3D skeletonization algorithm applied on brain vascular structure. This method seems suitable to tubular substances which are based on the application of the minimum cost-spanning tree using Dijkstra's algorithm [17].

V. CONCLUSION

The algorithm suggested in this research is an upgrading to the existing algorithms, in which adjusting cellular state set with combination of breeding and mature states would reduce the times of cellular state turnover. The final result obtained by Dijkstra algorithm remains dependable. Some shortest paths may exist in the shortest path calculation, but only one of them had been recorded by traditional algorithm. Sometimes it comes out with incorrect result because of inaccurate regulation. However, with an innovative method implemented, the algorithm suggested in this research will enable all the shortest path information to be recorded and then let the multi-paths problem to be solved effectively.

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