Research on the Relationship Between Business Process Input and Output Based on the Directed Graph

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Abstract: Enterprise digital transformation needs to sort out a large number of business processes in order to achieve the goal of management value. According to the requirements of enterprise digital transformation, the value of business process needs to be identified in the process design stage, that is, the relationship between input and output of the business process needs to be analyzed. However, due to the poor performance and slow speed of the traditional business process input and output analysis method, it can't meet the performance requirement. Based on this, this paper proposes an efficient business process input and output analysis method to facilitate the realization of digital transformation of enterprise management.

Keywords: Enterprise digital transformation; Business process; Input/output analysis

1 Introduction

In the digital transformation of enterprises. The digital transformation of enterprises[1] needs to open up business processes and data in all areas of the enterprise, break down department walls and data silos, realize the integration of global business and data, empower business and provide accurate insights for decision-making[2]. According to the characteristics of enterprise digital transformation, enterprise digital transformation mainly includes two parts: business process design and digital process development. The business process[3] is completed by the business department, and the digital process[5] is completed by the information technology department, so as to realize the decoupling between the business process and digital process. In the design stage of the business process, it is necessary to analyze the input of the business process comes from which other business process, and the output of the business process can be as which other business process input[4], so as to provide accurate input for the development of the digital process[6], improving the efficiency of information system development.

When traversal method[7] is used to calculate the input-output relationship of business processes, assuming that the number of business processes is N, the average number of input and output of business processes is also N, then its computational complexity is $O(N^4)$. When the number of

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business processes increases rapidly, the calculation speed of this traversal method will decrease exponentially, and it is difficult to meet the performance requirements for the calculation of input and output relationships of a large number of business processes, which affects the efficient development of digital transformation of enterprise management.

Based on this, this paper proposes an efficient method to calculate the input and output relationship of business processes, which abstracts the input and output relationship of business processes into directed graph adjacency matrix[8], and then the input and output relationship can be calculated by calculating the out[10] and in[11] degrees of directed graph adjacency matrix[9]. The method proposed in this paper reduces the time complexity from $O(N^4)$ to $O(N^2)$ when calculating the input-output relationship of business processes, which greatly improves the performance of calculating the input-output relationship of business processes and effectively supports the efficient development of enterprise digital transformation.

2 Method

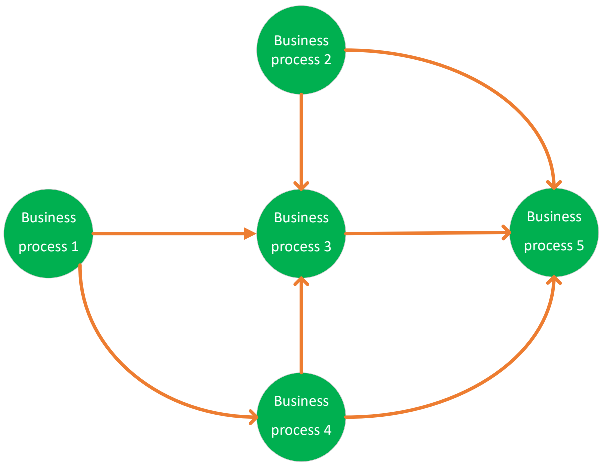

Figure 1 A simple example of the business process input/output relationship

The input and output relationship of the business process is shown in Figure 1. In Figure 1, the output of business process 1 is the input of business process 3, so there is a relationship between business process 1 and business process 3. In addition, business process 5 has three inputs from business process 2, business process 3, and business process 4, so business process 5 has a relationship with them. The purpose of this article is to analyze and statistics this input-output relationship between business processes.

There are two difficulties in calculating the input-output relationships of business processes. The mutual reference of input and output between business processes will form a complex network. When the number of business processes increases sharply, the relationship network between the input and output of business processes will become very large, resulting in complex analysis of the input and output relationships of business processes. If the traversal method is used to calculate the input and output relationship between business processes, assuming that the number of business processes is n, and the average number of input and output of business processes is n, then the time complexity is $O(N^4)$. Therefore, when the number of business processes increases sharply, the computing speed will decrease exponentially, making it difficult to meet the performance requirements.

Aiming at the above problems, this paper proposes a method to abstract the problem of calculating the input-output relationship of business processes into a mathematical problem of calculating the out-degree and in-degree of the adjacency matrix in a directed graph. The method proposed in this paper is explained as follows.

In a directed graph, a business process can be regarded as a vertex in the directed graph, and the input and output relationships between a business process and other business processes can be represented by arcs with arrows in the directed graph. The adjacency matrix of a directed graph is a two-dimensional array[12] representing the adjacency relations between vertices in the directed graph. If vertex V1 has an edge pointing to vertex V2, the corresponding position in the adjacency matrix is set to 1, and vice versa. Calculating the adjacency matrix is equivalent to recording the relationship between the input and output of a business process and the input and output of other business processes. After calculating the entry degree of each vertex in the adjacency matrix of the directed graph, it is equivalent to calculating the relationship between the input of the business process and other business processes. After calculating the output of each vertex in the adjacency matrix of a directed graph, it is equivalent to calculating the relationship between the output of a business process and other business processes.

Table 1 The algorithm of Adjacency matrix calculation

Algorithm 1: calculate the adjacency matrix

Input: a list of business process

Output: a adjacency matrix of the directed graph

```
//get the directed graph G of business process.
List G=getGraph();
for(i = 0;i < G->n;i++)
{
    for(j = 0;j < G->n;j++)
    {
        //initial the adjacency matrix
        G->edges[i][j] = 0;
    }
}
for(k=0;k<G->e; k++)
{
        // build the adjacency matrix
        G->edges[i][j] = 1;
}
return (G, G->edges);
```

Set the digraph G=(V, E), where V is the set of all vertices in the digraph, V ={V_1,V_2,V_3,V_4,V_5... Vn}, E is the set of all edges in the digraph. Let G->edge[G->n][G->n] be the two-dimensional array representation of the adjacency matrix in the directed graph G, then the algorithm for calculating the adjacency matrix is shown in **Algorithm 1**. In **Algorithm 1**, G->n is the number of vertices in the directed graph, referring to the number of business processes. If the vertex i to j have an edge, G-> edge [i] [j] = 1, otherwise the G-> edge [i] [j] = 0.

Table 2 The calculation algorithm of the out degree and in degree of the directed graph.

Algorithm 2: calculate the out degree and in degree of the directed graph.

Input：a adjacency matrix of the directed graph

Output: out degree and in degree of the directed graph

```
//Set the input map to save in degree info
Map<int,List<int>> input;
//Set the ouput map to save out degree info
Map<int,List<int>> output;
for(i = 0;i < G->n;i++)
{
   for(j = 0;j < G->n;j++)
   {
        if(G->edges[i][j] = 1 && !visited[i][j]=1)
      {
            visited[i][j]=1;
          //In degree
          input.get(j).add(j);
          //Out degree
          output.get(i).add(i);
        }
    }
  }
}
return (input,output);
```

The calculation algorithm of out degree and in degree in directed graph is shown in **Algorithm 2**. Input.get (j). add(j) represents the set of business processes, which provides input for business process J. Output.get (I).add(I) represents a collection of business processes, in which the output of business process I as their input.

3 Experimental result

The experimental environment was an X64 desktop computer with i5 processor, 3.2ghz processor frequency and 8G memory. The traversal algorithm and the method proposed in this paper are realized by code respectively, and the experimental results are shown in the figure below. The experimental results are shown in the figure above.

Table 3 The comparison of experimental results

the number of business process	500	600	700	1000
traversal method	62s	130s	240s	980s
our method	2s	3s	3.9s	5.3s

The comparison of experimental results is shown in Table III. The first line represents the number of business processes, and the second line represents the elapsed time analyzed by the traversal algorithm on the corresponding number of business processes. The third line represents the elapsed time analyzed by our method for the corresponding number of business processes. For example, when the number of business process is 500, the traversal method takes 62 seconds, compared with just 2 seconds using our method. When the number of business process is 600, the traversal method takes 150 seconds, but our method only using 3 seconds. When the number of business process is 1000, the traversal method takes 980 seconds, but our method only using 5.3 seconds. From above results, it is obvious that our method greatly reduces the time. In a word, the experimental results show that compared with other methods, the proposed method has obvious advantages in performance and speed.

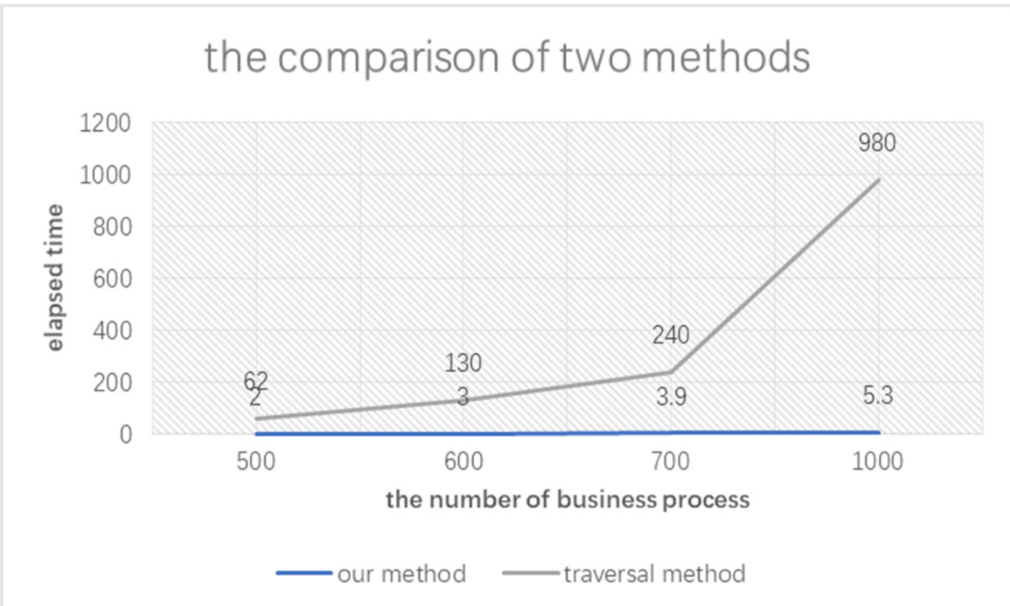

Figure 2 Comparison of time consumption trends between the two methods.

In order to verify the performance stability of our method, another experimental analysis is performed, and the experimental results are shown in Figure. 2. As shown in Figure 2, it is a comparison of time consumption trends between the two methods. From the experimental results, the performance of the traversal method is unstable and varies greatly with the number of business processes, while our method is very stable, and the speed does not change much under different numbers of business processes. Therefore, our method has a particularly distinct advantage over other methods.

4 Conclusion

Through the above description and experimental analysis, compared with other methods, our method has obvious advantages in speed and stability. Through our method, the input-output relationship of the business process can be analyzed in the business process design stage, so that the business process can be iteratively optimized according to the analysis results, so as to achieve the purpose of improving the quality of the business process and facilitate the realization of the digital transformation of enterprise management.

References

[1] Peng D. The Research and Implementation in Digital Transformation of Manufacturing Enterprises[J]. Journal of Physics Conference Series, 2021, 1820 (1): 012098.

[2] Koumas M, Dossou P E, Didier J Y. Digital Transformation of Small and Medium Sized Enterprises Production Manufacturing[J]. Journal of Software Engineering and Applications, 2021, 14(12): 24.

[3] Chandra Y, Willis R, Windoro C, et al. Business Process Design for Widuri Indah School Management System with the Support of Cloud Computing. 2020.

[4] Beausoleil A M. Introduction to Business Design[J]. Springer Books, 2022.

[5] Essig P, Liewald M, Bolay C, et al. Digital process support in toolmaking by using optical metrology[J]. IOP Conference Series Materials Science and Engineering, 2019, 651:012026.

[6] Heidi P, Thomas W, Ari H, et al. Digital Design Process and Additive Manufacturing of a Configurable Product [J]. Advanced Science Letters, 2013.

[7] Nishio T. Traversal method of processing tree structure information and apparatus using the same: US, US4868743 A [P]. 1989.

[8] Aji B H, Sugeng K A, Aminah S. Characteristic polynomial and eigenvalues of antiadjacency matrix of directed unicyclic flower vase graph[J]. Journal of Physics: Conference Series, 2021, 1722(1):012055 (8pp).

[9] Anzana N, Aminah S, Utama S, et al. Characteristic polynomial of anti-adjacency matrix of directed cyclic friendship graph[J]. Journal of Physics Conference Series, 2020, 1538:012007.

[10] Asahiro Y, Miyano E, Ono H. Graph classes and the complexity of the graph orientation minimizing the maximum weighted outdegree [C]// Discrete Applied Mathematics. Elsevier B.V. 2011:498-508.

[11] Prayitno M, Utama S, Aminah S, et al. Properties of adjacency, in-degree Laplacian, and out-degree Laplacian matrices of directed cyclic sun graph[C]// PROCEEDINGS OF THE 8TH SEAMS-UGM INTERNATIONAL CONFERENCE ON MATHEMATICS AND ITS APPLICATIONS 2019: Deepening Mathematical Concepts for Wider Application through Multidisciplinary Research and Industries Collaborations. 2019.

[12] Pevny T, Bas P, Fridrich J. Steganalysis by Subtractive Pixel Adjacency Matrix [J]. IEEE Transactions on Information Forensics & Security, 2010, 5(2): 215-224.