A model of time management based on tree in Product Data Management

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Abstract. According to the distribution characteristics of workflow time node, this paper studies the time node representation of a structured workflow and describes in detail the definition of workflow time node in Product Data Management, then puts forward a tree design model. From the time property of different control structures, we can find the key activities of the workflow model and dynamic forecast the period of project, which lays a foundation for the adjustment and optimization of workflow process.

Introduction

This paper defines a time node model of tree based on structural optimization, which greatly reduces the computational complexity but very versatile, the current mainstream workflow model based on Petri- nets[1] can be mapped to this time node model to determine the critical path. We can arrange the work flow and configure resources reasonablely according to the schedule and progress which are gotten from the dynamic analysis of the critical path[2] of project, so as to shorten the construction period. Workflow structure can also be adjusted to optimize the execution order of activities and decompose activities into parts to improve parallelism and determine the critical path again until meet the requirements of project.

The establishment of the model

Basic control structures in general workflow model. Workflow Management Coalition defines six typical workflow execution control structure, they are Sequence, AND-split, AND-join, OR-split, OR-join and Loop[3, 4]. These control structures are represented in Fig. 1.

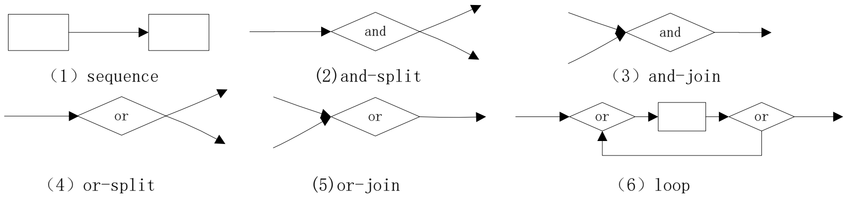

Fig. 1 The control structure of workflow

The logical structure of a workflow control. Workflow model expression can be simply defined as WF = <A, L>, Where A is the collection of activities, L is the connection between activities, L∈{AND,OR,XOR}. The sequence is expressed by AND, AND-split and OR-split are expressed by OR judging from time. OR-join and AND-join can be viewed as a kind of special sequence, no need to be treated separately. Loop is a complex relationship between the previous five kinds, so the relationship between the nodes can be simplified as sequential, parallel and branch. Then we can have a logical deduction for workflow time node model with the basic units of previous logical relationship.

Time node model of the workflow. Workflow process can be expressed as a tree of time node based on six kinds of basic control model. The tree has two types of nodes, one type represents the active node, another is the relationship between the nodes. These two kinds of nodes are defined as follows:

Active node: It represents each step of activity in workflow process and records the properties related to the activity, the structure is represented as ActivityNode <S, T, ST, AT, K, D>.

Relations nodes: It shows the relationship between activities and records travel path of the activity, the structure is expressed as RelationNode<T, ST, K , L>.

The descriptions of the property are shown in Table 1.

Table 1 The properties of node

Name	Description
S	Status: the status of node, 0 indicates the node doesn't start, 1 means it's executing, 2 means it has been completed.
ST	Schedule Time: the node's execution time of the plan.
AT	Actual Time: the actual execution time of the node.
K	Key: a boolean variable, 0 means it is not the key node, 1 means it is the key node
CD	Complete Degree: it represents the completion of the node (ST/AT)
T	Type: type of node or relationship, L indicates it's a leaf node, S represents the sequence, P is parallel, B is branch.
L	Loop Frequency: cycles, the default value is 1 which indicates that there is no cycle.

Generation rules. Leaf nodes represent atomic activities, relationships between activities are represented by their parent node. P_i is the probability of being selected of branch A_i. Specific conversion and the calculation of path are shown in Table 2.

Table 2 The tree structure of nodes and calculation of time path

Type	Schedule Time
Sequence	$\sum_{i=0}^{n} A_i.ST \times$ Sequence.L
Parallel	Max(A.ST…An.ST)×Parallel.L
Branch	$\sum_{i=0}^{n} A_i.ST \times P_i \times$ Branch.L

We can build a tree to represent a complete project with the three basic structure, thus generally calculating the critical path of workflow and forecasting time limit for a project. The tree is the staff get from the preconfigured templates or add their own nodes to get generated at the beginning of the project, the operation of the project is the changing process of the status of tree node .

The relevant algorithm to estimate the critical path and time limit for a project.

Mark the critical path: Traditional critical path is based on the network diagram, but here we use a method of weighted critical path[5] based on tree structure, namely calculating the weighted time of the optional path and the weight corresponding to each branch.

Estimate the time limit for a project: We have already completed the calculation of project plan time and markers of critical path, t_1 represents the planned completion time of remaining nodes, { A_0 , A_1 , A_2 … A_n }are the nodes whose value of key is 1 and value of status is 2, namely they are the key nodes which have been completed. AT represents the actual execution time of the node in Table 1, time spent on the project is described as follows:

$$t_0 = \sum_{i=0}^{n} A_i.AT \quad (1)$$

CD represents the completion of the node in Table.1, ΔCD is defined as:

$$\Delta CD = CD - 1 \quad (2)$$

The uncertainty has 2 kinds, the positive uncertainty means early, the negative uncertainty means delay. As with Δ CD/2 as the standard deviation of the uncertainty of a node, with 2 times the standard deviation of link uncertainty as the estimated of uncertainty of the link[6]. Assuming that the duration of each step is independent, ΔE represents the uncertainty of the nodes, then we can calculate it according to the central limit theorem:

$$\Delta E = \frac{2\sqrt{\sum_{i=0}^{n}\left(\frac{\Delta cd_i}{2}\right)^2}}{n} = \frac{\sqrt{\sum_{i=0}^{n}\left(\Delta cd_i\right)^2}}{n} \tag{3}$$

ΔE_+ is the early uncertainty, ΔE_- is the delay uncertainty, T is the period of project. Calculate the early uncertainty and delay uncertainty of project according to the uncertainty of the completed nodes, assume that the number of early nodes is m and the number of delay nodes is n, then we can forecast the period of project as follows:

$$T = \frac{t_1}{\Delta E_+ \cdot \frac{m}{m+n} - \Delta E_- \cdot \frac{m}{m+n} + 1} + t_0 \tag{4}$$

The example

The workflow of the model showed in Table 2 is used to illustrate the method in this paper, the tree structure correspond to the project is shown in Figure. 2. The leaf nodes in the graph represent the various activities of the project, the completion time of project plans is known and the project does not start, the attributes of the nodes are defined strictly in accordance with Table.1.

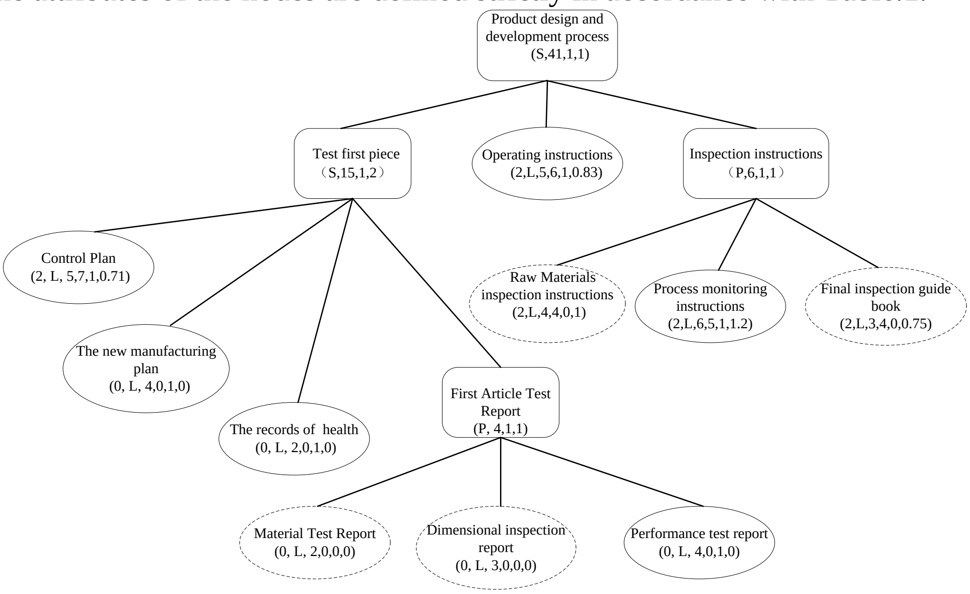

Fig. 2 Structure of the project

We can get plan completion time of all nodes according to the algorithm and simple operation, then label the key nodes, for example：

(1)Material Test Report , Dimensional inspection report and Performance test report are the most basic leaf nodes, the type of their parent First Article Test Report is P, L has a value of 1 indicates no circulation, so the Schedule Time of First Article Test Report is 4, which is the maximum value of its children.

(2)The parent node of Test first piece, Operating instructions and Inspection instructions is Product design and development process, the value of K in Product design and development process is 1 and the value of T in it is S, so the value of K in Test first piece, Operating instructions and Inspection instructions are set to 1.

Eventually we get that the Control Plan, the new manufacturing plan, the records of health, Performance test report, Operating instructions and Process monitoring instructions are the key nodes(the ellipses of solid line in the Fig. 2), the plan period of project are 41 days.

At a certain stage of the project, the Operating instructions actually spend six days, the Raw Materials inspection instructions spend four days, Process monitoring instructions spend five days, the Final inspection guide book spends four days, the Control Plan spends seven days, the other nodes don't start. The Control Plan, Operating instructions and Process monitoring instructions are key nodes, in addition, the Control Plan and Operating instructions are the delay nodes, the uncertainty of them are {－0.29,－0.17}; the Process monitoring instructions is a early node, its uncertainty is {0.2}.

$$\Delta E_{-} = \frac{\sqrt{(\square\, 0.17)^2 + (\square\, 0.29)^2}}{2} = 0.17$$

$$\Delta E_{+} = \frac{\sqrt{0.2^2}}{1} = 0.2$$

$$T = \frac{41 - 5 - 6 - 5}{0.2 \times \frac{1}{3} - 0.17 \times \frac{2}{3} + 1} + 7 + 6 + 5 = 44\text{days}$$

According to the current schedule, the time limit for the project forecast are 44 days.

Summary

This paper puts forward a time node model of tree based on structural optimization. This model has a simple structure, so we can calculate the critical path and time limit for a project quickly, it is allowed to adjust the structure of workflow in the operation of the project according to the data real-time. Whats more, it will produce a new path after the workflow structure changing, but the path can be recalculated and analyzed until meet the requirements of enterprise. The basic model lays the foundation for other aspects of the research in project, this method can be extended to other aspects of the project such as resources optimization and cost estimation. This paper only gives the process of workflow control and basic properties of core modeling method in terms of modeling, so the modeling method of factors such as resources and organization is the next step of research contents. Furthermore, how to introduce the factor of relationship between the nodes in terms of time prediction, which makes the method in this paper be really effective in speculating a workflow model with complex relations also needs further research.

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