Research on Cable Route Planning Based on Secondary Development of CATIA

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Abstract. With the development and minimization of electronics, it is necessary to plan the cable route scientifically. In order to solve the defects of the traditional method of cable layout, a cable route planning method on Secondary Development of CATIA is proposed in this manuscript. For the complicated electrical equipment, the cable path searching is implemented by improving ACO. After that, secondary development of CATIA has been proposed in order to plan the cable fast and effective. In the end, based on the case of an aeronautical product the maneuverability of the method has been verified.

Introduction

With the development of electronics toward diversification and miniaturization, the structural space in the system is becoming smaller and smaller. How to plan the cable route effectively is one of the most important contents of the cable layout design. The speed and reliability are unable to meet the requirements of development and production because traditional method of three-dimensional cable layout is mainly based on the experience of manual cabling. Moreover, it can be seen in [1] that most of the existing cable layout designs is only in two-dimensional plane, so the cabling effect is not realistic enough, which cannot reflect the laying effect of the wiring harness in the whole machine. It will bring a lot of troubles for subsequent processes.

As the core of the cable route planning-path searching algorithm, many researches have been carried out by domestic and foreign scholars. In [2], a RRT algorithm based on obstacle detection is advanced. This method can effectively solve the problem of pipeline automatic layout along the structural surface under complex structure conditions. However, due to the complexity of the pipe layout, the engineering constraints are not fully considered. In [3], automatic pipe layout design and optimization method based on improved A* algorithm is submitted, which can quickly obtain a path satisfying engineering constraints, but the interaction influence between pipelines is not considered.

Aiming at solving the problems of the present cable route planning, this paper advances an automatic cable layout design method through optimizing and improving the path search algorithm, which use CATIA V5R19 as a platform and use CAA to conduct secondary development.

Cable Route Planning Model

Cables are flexible, and their size, shape and spatial location are constrained by the product structural space. Therefore, the cable route planning should be considering the mechanical properties, electrical properties, regional environment and maintainability. Since the key point of this paper is the implementation method of route planning and [4] have made significant research on cable route planning in the literature, the route planning model here draws on the cable route optimization model proposed in the literature.

Using the spatial coordinates Q (X, Y, Z) to express the cable route, the optimization goal can be expressed as:
\[ Q^* = \min Q_k . \] (1)

\( Q_k \) represents the sum of the distance between each two path points, which can be calculated as:

\[ Q_k = \sum_{m=1}^i \sqrt{(x_{ij} - x_{i(m+1)})^2 + (y_{ij} - y_{i(m+1)})^2 + (z_{ij} - z_{i(m+1)})^2} . \] (2)

In order to meet the needs of the research, the cable route planning model is simplified appropriately without affecting the result of cabling. The optimized mathematical model is shown as

\[
\begin{align*}
\text{Path}(Q) &= Q^*(x, y, z) \\
Q^* &= \min P_k \\
D_E &> D_0 \\
L_S &\geq L_0 \\
V_O &\geq V_S \\
s_q &\geq s_r.
\end{align*}
\] (3)

where, \( D_E, L_S, V_O, S_q \) refer to the electrical compatibility distance, bend radius, operating space volume, and non-interfering window area in the layout design of cable. \( D_0, L_0, V_S, S_r \) refer to the corresponding constraint value.

**Cable Route Planning Based on Ant Colony Optimization**

Ant Colony Optimization (ACO) is a probabilistic algorithm of path optimization. To apply it to the cable path searching, a corresponding suitability improvement need to be required.

**Construction of ACO Model**

The idea that ACO is applied to path optimization is as follows: If people regard the ant's walking path as feasible solution, then all the paths of ant colony form the entire solution space. The shorter the path, the more pheromones. As a result, the number of ants choosing this path will gradually increase, and its pheromone will be further increased. With the pathfinding, all the ants will be concentrated in the shortest path which is the optimal solution. Because of it, model can be constructed as:

The probability that ant \( k \) (\( k = 1, 2, \ldots, m \)) choose a path during pathfinding is proportional to the amount of information on that path and the associated heuristic information. If \( \eta_i(t) \) are used to represents the function from point \( i \) to point \( j \), \( \tau_{ij}(t) \) to represents the concentration of pheromones in the path \( ij \), \( \text{tabu}_k \) (\( k = 1, 2, \ldots, m \)) to represents the point that the ant passes now, the state probability of the ant \( k \) turning from point \( i \) to point \( j \) at time \( t \) can be calculated as:

\[
p_{ij}^k(t) = \begin{cases} 
\frac{[\tau_{ij}(t)]^\alpha \cdot [\eta_i(t)]^\beta}{\sum_{j \in \text{allowed}_k} [\tau_{ij}(t)]^\alpha \cdot [\eta_i(t)]^\beta}, & \text{if allowed}_k \\
0, & \text{else}
\end{cases}
\] (4)

where, \( \text{allowed}_k = \{C-\text{tabu}_k\} \) refers to ant optional point set; \( \alpha, \beta \) refer to heuristic factor and expectation factor. In general, the state probability is equal to the reciprocal of the distance of the path \( ij \), considering the constraint of the cabling space environment, the path distance here is the weighted
distance of the fusion electromagnetic interference. Since the old information will fade away over time as new information is stored, $\tau_{ij}(t)$ should update appropriately, so the pheromone concentration of the path $ij$ at moment $t + n$ can be calculated as:

$$\begin{cases}
\tau_{ij}(t+n) = (1-\rho) \cdot \tau_{ij}(t) + \Delta \tau_{ij}(t) \\
\Delta \tau_{ij}(t) = \sum_{k=1}^{m} \Delta \tau_{ij}^k(t)
\end{cases}$$

(5)

where, $\rho$ denotes the volatile coefficient, and the range of value is $[0,1]$, then $1-\rho$ can be used to represent the residual factor. $\Delta \tau_{ij}^k(t)$ represents the amount of information released by ant $k$ on the path $ij$, then $\Delta \tau_{ij}(t)$ represents the total increment of information on the path $ij$ in a single cycle, and it may be set to 0 at the initial time.

**Search Strategy Improvement**

The general path searching is based on the environment model. This paper draws on the method proposed in [5] to construct the grid point set of the cabling area.

As shown in the Figure 1, if the current path point is in $P_{\text{now}}$ plane, and the plane $a$ is the plane of the next path point searched by the algorithm, the set of path points which are available to choose is:

$$\begin{cases}
(i_a, j_a, k_a) \\
i_a = i + 1, \\
j - 1 \leq j_a \leq j + 1, \quad k - 1 \leq k_a \leq k + 1
\end{cases}$$

(6)

Then people should determine whether it is necessary point based on the cabling requirements. If it is necessary point, estimate whether it meets the constraints. If it conforms, it is a safety node. According to the information of each node, select the safe node and write in allowed table.

**Cable Path Searching Process Based on ACO**

According to the analysis above, it can be seen that the process of cable path searching includes gridding of cabling space, construction of allowed table, determination of path points and pheromones updating, etc. The process can be summarized as:
Firstly, initialize each parameter. Build a model of cabling space and initialize the allowed table. Secondly, start the loop. Remove non-compliant points from the allow table and update the pheromone partly. Thirdly, determine whether to traverse all the ants. If \( k \geq m \), all pheromones should update. Finally, determine whether to meet the end conditions. If the answer is yes, output the best result.

**Cable Route Planning Based on Secondary Development of CATIA**

CATIA cannot meet the complicated nonlinear analysis, because the CAE function of CATIA is limited. Therefore, this paper use CAA to carry out secondary development of CATIA.

**Interactive Toolbar Implementation**

Steps of interactive toolbar implementation are as follows:

The basic steps are as follows:

Step1. Create workspaces and frameworks files and add some interface functions in "identitycard.h" that may be used in later programming.

Step2. Add the menu and toolbar. Firstly, select "Add CAAV5 Project", "Add CAAV5 Item" to add a new menu bar in CATIA. Secondly, use "CreateCommands", "CreateToolbars" to create new commands and toolbars. Thirdly, use the "BITAssemHeader" to establish correspondence between the command name and the toolbar pointer. Fourthly, use "NewAccess" to add a menu window associated command with the incident by "SetAccessCommand", set the side-by-side relationship between the toolbar by "SetAccessNext", and add toolbar display by "AddToolbarView". Fifthly, create the menu and toolbar name and add the toolbar icon. Finally, update the project, rebuild mkmk, and enter "Cnext" in the "runtime window" to generate related toolbars.

Step3. Create dialog box and respond to commands. Firstly, click "Add CAAV5 Item" to add the dialog box. Secondly, double-click the controls in need and select "CallBack mapping" function type in order to build functional framework. Finally, rewrite the "Activate" function in the original function to connect the command with dialog box.

**Implementation of Layout Optimization Method**

This section is mainly to invoke the relevant interface functions in the framework of the CAA for the purpose of encoding the various control functions in C++ programming language, which is based on the flow diagram and the method that generate path points in CATIA by using ACO.
First of all, enter constraints. This step requires people to input the information which is needed for the cable route planning, set the grid precision and the level of various constraints (set the weight coefficient range of various constraints). After that, plan the cable route. This step requires people to standardize the input information, grid cabling space, plan the cable route which is based on ACO and generate path points in CATIA. Finally, optimize energy and generate cables. This step requires people to call the cable generation module in CATIA, select the points obtained in the above path planning and set the maximum allowable bending radius of the curve in order to generate the virtualized cable; then, import the cable parts into the electronic prototype. The cable generation module is discussed in [6].

Case Study
In this paper, the equipment cabin of an aeronautical product is used to verify the method. There is a control device in the equipment cabin which is used to provide power for other parts. This example is mainly to complete the cable route planning between the device and other electrical equipment. The result of cabling can visually show the cable route, alignment direction and bending radius of the cable because the whole job is done in CATIA. Cable layout optimization processes of the control device is shown as:

![Cable Layout Optimization Processes of The Control Device](image)

Figure 3. Cable layout optimization processes of the control device.

From the case we can learn that the method advanced in this paper is easy to operate and has a good effect. The cable route can generate automatically by using this method.

Summary
In this paper, all aspects of equipment cabling constraints are considered and then a method of cable route planning based on secondary development of CATIA is proposed for the complicated electrical equipment. The main work can be summarized for the following three parts.

- Based on analyzing the characteristics of cable route planning, ACO has been improved in order to implement cable path searching.
- Use CAA to carry out secondary development of CATIA for the purpose of planning the cable route rapidly and effectively.
- Based on the case of an aeronautical product, the feasibility of the method in this paper is verified.

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References


