Search Strategy Study of Piping Features Location Based on Smartline Model*

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Abstract The problem of features location and label occurs frequently in the production of many types of engineering CAD. For the efficiency of features location in piping CAD system, this paper presents strategies according to the characteristics of pipe-lines in plan & section drawing. Some methods of heuristic search based on smart-line model are introduced which make it possible to accomplish automatic placement of pipe-line features in local search space.

Key words Feature location, search strategy, heuristic search, algorithm, piping, CAD.

Tagging graphical objects with text labels is a fundamental task in the design of many types of informational graphics. Usually there are three label-location tasks identified: labeling of point features, line features, and area features[1~3]. The three placement tasks share a common combinatorial aspect when multiple features are present. The complexity arises because the placement of a label can have global consequences due to label-label overlaps. The problem and many of its interesting variants are NP-hard. The essential problem is combinatorial optimization. Many researches have been reported for overcoming combinatorial explosion, just like greedy random adaptive search procedure[4], simulated annealing, tabu search, genetic algorithm and their integration[5,6]. Some graph theoretic methods were presented for solving 2D or 3D layer design[7~9]. Those algorithms suitable for some cases are not perfect. References[10,11] emphasized the intensification and diversification problem in metaheuristics and pointed out that it's an importance direction in researching the approximate scheme for special problem using special algorithm. Thus any complete search algorithm would be impractical, and any practical algorithm would be incomplete. This characterization is borne by the previously published algorithms, which fall into two classes: exhaustive search algorithms and local search algorithms. As expected, the exhaustive algorithms are computationally profligate, and therefore impractical for realistically sized labeling instances. So

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the key to the problems is a combinatorial optimization in local search space. The quality of labeling depends on the following factors: the amount of overlap; the amount of a priori preferences in the canonical set of potential label positions; the number of object features left unlabeled. Multiformity appeared in different application fields.

Features location is seen in its most essential form in piping CAD system, where text labels must be placed on plan & section drawing while avoiding overlaps with other objects. Sometimes there are more than 400 pipe-lines (pipe-line is a logical concept and a pipe-line is composed of lines and arcs physically) in a drawing, or even more than 1,000 pipe-lines. It is a puzzle for CAD scholars and experts to the search algorithms according to the characteristics of plan & section drawing. For this, references[12～14] presented a new division of pipe lines with the help of engineers, and introduced algorithms of heuristic search. Here we discuss something about searching and selecting strategy based on smart-line model.

1 Engineering Concept & Definition

References[12,14] discussed some concepts, such as object, feature text, box, pipe-line upside, pipe-line left, pipe-line right, smart-line model and so on. In this section, the others used in this paper read as follows:

(1) Pipe line center (Cp): The middle point of a pipe line.

(2) Box center (Cb): The center point of a feature text.

(3) Search space: The area where the features will be located, that must meet design standards and engineering requirements. Search space is a rectangular area. Its height is that of texts and its length is that of pipe line segment limited to the area selected by the user.

(4) Pipe-line feature: All attributes of pipe-line. Pipe line features include number of pipe-lines, elevation of pipe-line, and flow direction of material. The last one is just a small arrow randomly marked in anywhere of the pipe line, so it is easy to deal with. Here the features discussed are the number and elevation of pipe-line, just like "PR-2001-200-1P1-H" and "EL+12.345", consisting of material symbolic, sequence, nominal diameter, rating, heat insulation and elevation.

(5) Location constraints: The rules for pipe-lines feature location. There are many engineering constraints and location standards used by engineers in their practice. Some constraints about feature placement are abstracted for the algorithms introduced in this paper:

* Feature text must be placed along the pipe line.
* Feature text must be placed on pipe line upside.
* Height of feature text in a drawing is fixed.
* No overlap exists between a feature text and another feature text.
* Feature text had better be placed in the middle of pipe line.
* A small amount of overlap exists between feature text and objects.

(6) Amount of slopping over (As): The number of pipe-lines whose feature text is not located in its search space. For the features left, we weaken engineering constraints and extend search space. This is an important datum to check the quality of placement.

(7) Amount of overlap (Ao): The number of times for calculating the objects crossing all boxes. This is another important datum to check the quality of placement. The set of all boxes is:

$$s_{box}=(box_1,box_2,...,box_n),$$

$$A0=\sum_{i=1}^{n} OVERLAP(box_i).$$

(8) Degree of uniformity (Du): A parameter to check the uniformity of plan & section drawing. The defini-

tion is given.

The center point set of all boxes is:

$$CB=\{cb_1,cb_2,cb_3,\ldots,cb_n\},$$

$$Du=\sum_{i=1}^{n-1}\sum_{j=1}^{n-i} distance(cb_i,cb_{i+j}).$$

2 Search Strategy Research

In references[12,14], after we checked a lot of engineering blueprints, several patterns which described the layout of pipe-line were abstracted from plan & section drawing. For extension later, we epurated some pattern features and formed a template library. So the process of pattern recognition is that of template mapping. The steps are: firstly, user selects the area to be located; secondly, the pattern is recognized from matching template library; thirdly, order the objects according to the amount of overlap (Ao) in the search space; fourthly, get the features from smart-line model; and finally place features based on some rules.

2.1 Search strategy

The search strategy here affects the aesthetics of the layout. In engineering CAD system, any plan & section drawing which meets the requirements of constraints is good. But the layout impression will be quite difference using different strategies. Some of the search strategies used in practice are:

* Center location (CL): The feature text is placed on the middle of pipe line, no consideration about overlapping. This is the simplest mode for placement.
* Left first (LF): The leftmost one in the set of potential positions.
  - The set of potential positions is given as $s=(s_1,s_2,s_3,\ldots,s_n)$.
  - Each $s_i(1\leqslant i\leqslant n)$ has a box, compute the cb_i, the center point set is $c=(c_1,c_2,c_3,\ldots,c_n)$.
  - The left point of pipe line is Pl, calculate the distance between Pl and $c_i(1\leqslant i\leqslant n)$, and have

$$Dleft=(d_1,d_2,d_3,\ldots,d_n)(1\leqslant i\leqslant n).$$

  - Location is: $LF(S)=\{s_i\,|\,d_i=\min(Dleft)\}$.
* Right first (RF): The rightmost one in the set of potential positions.
  - Given as above.
  - The right point of pipe line is Pr, calculate the distance between Pr and c_i, and have

$$Dright=(d_1,d_2,d_3,\ldots,d_n)(1\leqslant i\leqslant n).$$

  - Location is: $RF(s)=\{s_i\,|\,d_i=\min(Dright)\}$.
* Middle first (MF): The centermost one in set of potential positions.
  - Given as above.
  - The center point of pipe line is Cp, calculate the distance between Cp and $ci(1\leqslant i\leqslant n)$, and have

$$Dmid=(d_1,d_2,d_3,\ldots,d_n)(1\leqslant i\leqslant n).$$

  - Location is: $MF(s)=\{si\,|\,di=\min(Dmid)\}$.

MF is different from CL. There is no consideration about overlapping when using the CL strategy. But the ML one is different.

* Alternation between left and right (ALR): One strategy for the purpose of layout uniformity.
  - Give the order list of objects to be located: $L=(l_1,l_2,l_3,\ldots,l_n)$.
  - No_i location using strategy of LF.
  - No_{i+1} location using strategy of RF.
* The least overlap (Lo) : Locating on the position where the overlap is the least.
  - The set of potential positions is given as: $s=(s_1,s_2,s_3,\ldots,s_n)$.

- Computing Ao for each s_i, the set of Ao is $S_{Ao}:=\{a_1,a_2,...,a_n\}$.
- $LO(s)=\{s_i|a_i=\min(a_1,a_2,...,a_n)\}$.

* Synthesis location (Syn): Combination of all strategies above and the description is:

- Alt=0.
- Give the order list of objects to be located :$L=(l_1,l_2,l_3,...,l_n)$.
- For each $l_i\in L$ do computing, the set of potential positions is:

$$P_i=(p_1^i,p_2^i,p_3^i,...,p_m^i).$$

- Compare and get the set of the least overlap,

$$LO(P^i)=LO^i=\{lo_1,lo_2,...,lo_k\},1\leqslant k\leqslant m.$$

- If $k=1$, place feature on lo_k, else

$$MF(LO^i)=MF^i=\{mf_1,mf_2,...,mf_t\},1\leqslant t\leqslant k.$$

- If $t=1$, place feature on mf_t, else

  Alt=Alt+1, if Alt is odd, $LF(MF^i)=\{mf_{t1}\},(1\leqslant t1\leqslant t)$, then place feature on mf_{t1} else $RF(MF^i)=\{mf_{t2}\},(1\leqslant t2\leqslant t)$, then place feature on mf_{t2}.
- Repeat until all objects are located, $1\leqslant i\leqslant n$.

2.2 Performance test

Layout of pipe line has some peculiarity, and usually the size is large. So here we choose hexagon and octagon as test examples of the strategy listed above. The data are shown in the following table. (The objects of test are shown in Fig. 1)

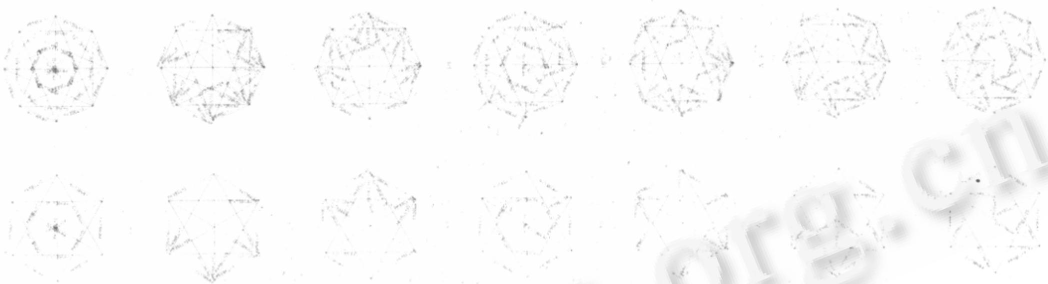

Fig. 1. The test examples

Table1 The test data list

EXAMPLES STRATEGY	Hexagon			Octagon		
	Ao	As	DU	Ao	As	DU
CL	11	3	2565	63	8	9072
LF	12	0	1422	48	1	6130
RF	12	0	1422	48	1	6130
MF	9	0	2594	56	3	9112
ALR	17	0	1618	52	1	7310
LO	2	0	1904	36	1	7015
SYN	2	0	2482	36	1	8994

CL strategy is easy to find the location, but the value of As is too big to meet the constraints of engineering. So this strategy should be given up.

LF and RF are the same from their inbeing. The test data are similar. But Ao is large, and not suitable.

MF is quite good for layout uniformity, but the values of As and Ao are not ideal .

ALR shows good capability about As, but Ao is very bad.

LO has an excellent behavior for Ao, and Du is not good.

SYN is a strategy that is the integration of all good ones listed, so all parameters are quite good.

In the engineering of piping CAD, there are hundreds of pipe-lines in a plan & section drawing. When template library is abstracted, we can select better strategy for different patterns, such as intersection pattern, circularity pattern and radiation pattern. The effect has been proved by 25 plan & section drawings of Yangzi Low Temperature Ethene Equipment.

3 Conclusions

The line-feature label-placement problem is a graphics-design problem of practical importance and causes difficulty in CAD system. Statistics given by petrochemical engineers show that it accounts for more than 90% design load for features location. Patterns abstracted cover more than 95% cases in engineering. PDSOFT is a petrochemical plant design system. The algorithm introduced in this paper has been used in PDSOFT for pipeline feature placement. Figure.2 shows a sample plan & section drawing.

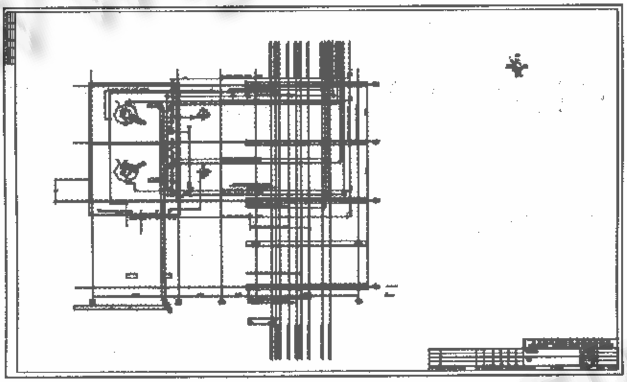

Fig. 2. A sample plan & section drawing

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基于智能线模型的管线特征定位搜索策略研究

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摘要 特征定位问题经常出现于各种工程CAD的系统研究中.为提高管道CAD系统中的特征定位效率,文章根据平剖图中管线的特点,提出了管线特征定位的若干策略,介绍了多种基于智能线模型的启发式搜索方法,使得管线特征的自动定位在局部范围内成为可能.

关键词 特征定位,搜索策略,启发式搜索,算法,管道,CAD.

中图法分类号 TP391