Line Recognition Method in Control Logic Diagram

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1. Introduction

As technology advances, digitalization is accelerating. Nuclear Power Plants (NPP) are no exception and digital logic designs are becoming commonplace.

There are two types of control logic drawings used in the Instrumentation & Control (I&C) design of NPP: Control Logic Diagram (CLD), which is a designer's drawing, and Vendor Logic Diagram (VLD), which is a manufacturer's drawing.

The CLD and VLD drawings owned by the NPP are scanned to computerize hardcopy drawings from pure drawings created in AutoCAD without noise. Computerized drawings exist in various formats such as jpg, tif, and pdf.

In addition, there are many practitioners of NPP who prefer printed hard copies rather than computerized drawings. In actual NPPs, many hard copies are used to verify and evaluate design integrity and signal flow.

In this paper, we are going to suggest a method for recognizing lines in drawings from noise-free drawings in AutoCAD to scan versions with noise.

2. Technology Background

In this section describes the background for line recognition of control logic drawings.

2.1 Hough Transform and Principal Component Analysis

When the widely used linear detection algorithms Hough transform and Principal Component Analysis (PCA) were applied to drawings, the following problems occurred due to the noise problem, which is a characteristic of scanned drawings:

a. Recognized as multiple straight lines due to distortion of straight lines in the drawing
b. A lot of overhead due to noise
c. A post-processing is very complex due to pseudo straight line (horizontal/vertical) detection

Like the problems dealt with in various papers [1], the inherent problems of the Hough transform could not be overcome.

2.2 Reference Resolution of Control Logic Drawing

Control logic diagrams are made in various resolutions. Among them, 4678 X 3308, the most widely distributed resolution, was selected as the reference resolution.

2.3 Line Characteristics of Control Logic Drawings

In the control logic diagram, only vertical and horizontal lines exist. There are no diagonals or curves. There are drawings created with the scan tilted while computerized, but they cannot be viewed diagonally. Therefore, only vertical and horizontal lines need to be detected.

2.4 Suggested Technology

To overcome the limitations of Section 2.1, we propose two (2) techniques to improve the line recognition performance.

a. Horizontal and vertical line detection
b. Connection line between symbols

3. Horizontal and Vertical Line Detection

3.1 Horizontal Lines Detection

Inspect the color of all pixels from left to right, starting at the top left of the image. It is assumed that the drawings are based on black-and-white drawings. When the color of the pixel is the reference color black, use it as the start of the line and measure the number of pixels of the reference color on the right side.

3.2 Reference of Line

Since the thickness and state (straightness of the line) of the straight lines in the scanned drawing are not constant, the length of the short connecting line was selected as the reference pixel of the line in the range where the characters in the drawing were not recognized as lines.

Table I shows the results of experiments with 30, 37, 40, 43, and 50 pixels to determine the reference pixel.

Table I: Line Recognition per Pixel

Drw No.	Line cnt	Reference Pixel (recognize(mis))				
		30	37	**40**	43	50
1	78	180(102)	89(11)	**82(4)**	82(4)	81(5)
2	163	236(73)	177(18)	**173(14)**	173(14)	173(14)
3	131	250(119)	149(18)	**137(6)**	137(6)	137(6)
4	152	497(345)	173(21)	**171(19)**	171(19)	171(19)
5	77	519(442)	99(22)	**91(14)**	78(5)	76(1)
6	121	237(116)	134(17)	**126(9)**	126(9)	126(9)
7	353	393(46)	351(56)	**348(53)**	339(52)	335(54)
8	172	214(48)	163(9)	**160(12)**	160(12)	158(14)
9	506	954(458)	566(76)	**550(78)**	547(81)	454(102)
10	133	405(272)	158(29)	**154(33)**	154(33)	120(47)

In Fig. 1, the value of the line detected at 37 pixel is stabilizing, and it seems that 50 pixel shows better results.

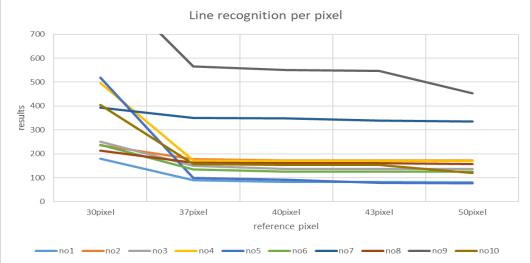

Fig. 1. Number of recognized lines for each pixel.

However, in Fig. 2, the false-detected value increases in both directions based on 40 pixels. In other words, if the pixels larger or smaller than 40 pixels are mis-detected or not recognized, the accuracy is lowered.

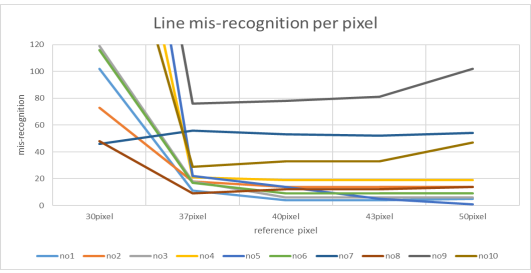

Fig. 2. Number of mis-recognized lines for each pixel.

Therefore, as a default value for judging horizontal lines, continuous 40 pixels were set.

3.3 Vertical Line Detection

It is processed in the same way as horizontal line detection (refer to section 3.1 and 3.2), and the direction is checked sequentially from top left to top to bottom.

4. Connection Line between Symbols

4.1 Connection and Exclusion of Connecting Lines

In the drawings, not only lines but also characters and symbols exist. Directly related to connecting lines are symbols. Symbols are recognized through YOLO and various recognition technologies. This paper does not deal with symbol recognition.

The position of the recognized symbol is connected with horizontal and vertical lines. And, lines, intersections and connecting lines in the area searched for by symbols are excluded.

4.2 Searching the Connector Line

Starting from the starting position of each horizontal and vertical line collected, check for any other intersecting lines. If there is an intersection, it moves to another line that intersects the current line and collects connection line information. If it is an end point of an extended line or an intersection connected to a symbol, the path traveled so far is stored and treated as a connecting line. It moves to the previous intersection position based on the position moved so far, and checks whether there is another branch line. Repeat again by moving the reference to another branch line. (Fig. 3)

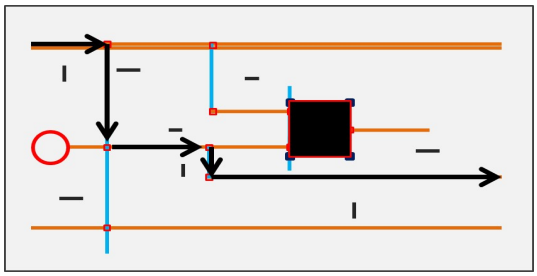

Fig. 3. connecting line search.

3. Conclusions

Control logic drawings used in nuclear power plants exist in various types, from hardcopy to electronic drawings in AutoCAD. A lot of experimentation and trial and error were needed to recognize the lines in these drawings.

In this paper, the most suitable line recognition algorithm beyond Hough transform and PCA was proposed to recognize lines in control logic drawing, and a reference pixel was presented.

Based on this technology, the line of the control logic drawing is recognized, and the control logic drawing is rewritten to reproduce the normalized vector drawing. This technology normalizes the control logic drawings that exist in various formats and becomes the basic data for simulating the drawings.

In the future, research using deep-learning technology is needed to recognize lines in drawings by reflecting real-time photos, curved photo drawings, and real-time images (videos).

REFERENCES

[1] J. S. Oh, Straight Line Detection Using PCA and Hough Transform", Journal of the Korea Institute of Information and Communication Engineering, vol. 22, Issue 2, pp227, 2018