DEVELOPING A PROTOTYPE OF QUALITY CONTROL EXPERT SYSTEM FOR OFFSET PRINTING DOT VARIATIONS TROUBLESHOOTING

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Abstract: Printing Quality Control Expert System (PQCES) mainly describes the use of an expert system, a branch of Artificial Intelligence (AI), in controlling offset printing dot variations. The system can be largely divided into three parts: the knowledge base, which standard data and fault judgment information are acquired from some quality control devices; the inference engine, in which heuristic rules are constructed according to experienced offset printing operators and appropriate paper records; and the user interface, which the expert system tool, Nexpert Object, is applied to process knowledge and information in the environment of Windows. For knowledge engineering, the knowledge acquisition and representation of dot variations are edited with the editors of Nexpert Object. For instance, several quality control devices, such as dot-gain scale, control bars...etc., are transferred into objects and rules. The prototype of PQCES is constructed with these rules and related data. It is not only a Decision Support System (DSS) for improving the quality of offset printing operation, but also a training system for offset printing trouble-shooting training for the entry-level trainees.

Introduction

As the main aspect of printing, the quality of offset printing has been discussed by several forerunners (Heidelberg, 1990; Huntsman, 1991). It is found that the quality of color printing is based on the fidelity of dot transfer from positive screen or negative screen to plate, offset blanket and printing paper both in color reproduction and offset printing with halftone method.

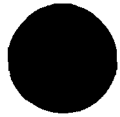
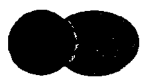
No.	Types	Normal	Dot Variations
1	Dot Gain		
2	Sharpening		
3	Circumferential Slurring		
4	Lateral Slurring		
5	Filling In		
6	Doubling		
7	Offsetting		

Fig.1 Simulation Syndromes of Dot Variations

System Architecture

There are several factors influencing the quality of offset printing: original manuscript, paper, press, printing plate, printing sequence, the attitude and the physiological condition of operators. An experienced printing operator can treat most of the above factors properly. But for high definition printing, some other instruments or scales can be used for improving the printing quality, such as control bars and dot gain scales. The problems of ink-water unbalance, slur, abnormal dot gain, solid ink trapping or transparency can be partly solved with these scales.

The prototype of PQCES was developed based on the development of Expert System with Nexpert Object . The objects, classifications, attributes and weight values of different dot gain variations were presented with the tools provided by Nexpert Object. Since Nexpert is an object-oriented software with the features of message passing, user-defined and external methods; extended and simplified rule syntax; enhanced inference engine performance and memory use on all platforms, its development environment is sufficient for the PQCES development. The system architecture was designed as a three-levels structure as shown in the Fig.2. The ground level is defined as system platform and consists of Nexpert Object version 3.0,

Knowledge Base of Dot Variations	
Database	Rule Base
1.Paper basis weight and thickness.	IF Dot variations
2.Press speed.	THEN
3.Printing sequence.	1.Show relational figures.
4..Fountain solution type.	2.Data transformation.
5.Ink type.	3.Message pass for inference engine.
6.Tack value.	4.Execute programs.
7.Blanket type.	5.Create or delete objects.
8.PH value of fountain solution.	6.Reset slot value.
9.Press pressure.	7.Evaluate new rules.
10.Others	8.Read/Write database.

Inference Engine
1.Backward chaining
2.Forward chaining.
3.Others.

System Environments
1.Dos 6.2 and Windows 3.1
2.Nexpert Object 3.0

Fig.2 PQCES System Architecture

Windows 3.1 and DOS 6.2 and a PC 486. The second level is defined as inference engine which consists of Backward chaining and Forward chaining. The top level is defined as the Dot Gain Variations Knowledge Base which consists of database and rule base.

System Development Procedure

The prototype of PQCES was developed according to the construction procedure of Expert System which was based on the principles of Software Engineering. Fig.3 depicts the flow chart of PQCES development procedure. The main procedures can be stated as the followings:

1. Literature review for the patterns of dot gain variations.
2. Cause analysis for the dot gain variation patterns.
3. Selection of hardware and software platforms.
4. Qualitative analysis for the effects of current scale controllers.

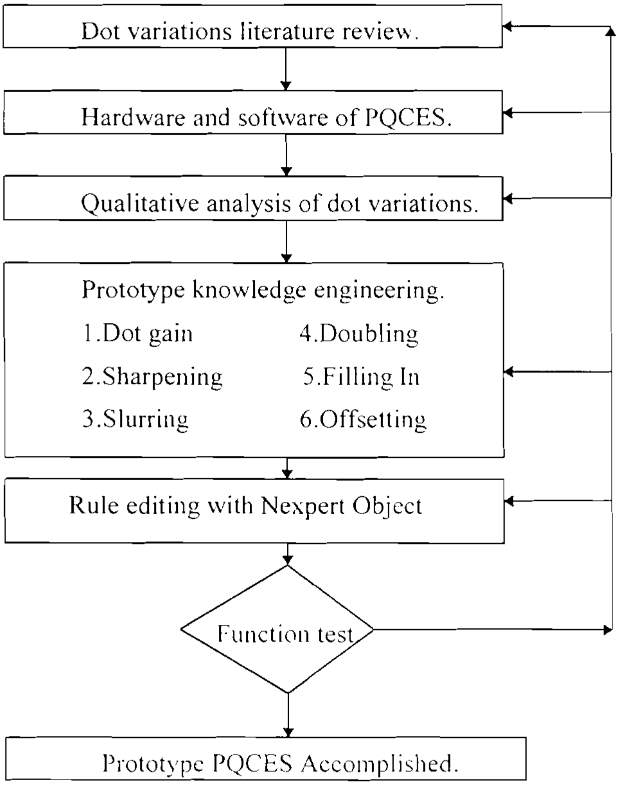


Fig.3 Development Procedure of the Prototype of PQCES

5. Troubleshooting rules setting for dot gain, filling in, sharpening, slurring, doubling and offsetting.
6. Knowledge base editing with Nexpert Object software.
7. System test and correction.
8. The accomplishment of prototype of PQCES.

Table 1. Major Job Items of Knowledge Acquisition Procedures

Procedure	Steps	Job Items
1.Problem Definition	1.Literature review for dot variations 2.Expert interview	1.Making hypotheses for improving the quality of offset printing 2.Defining dot gain, filling in, sharpening, slurring, doubling and offsetting
2.Problem Analysis	Dot variation syndrome analysis	1.Making cause-effect relationship chart 2.Classifying troubles systematically
3.Problem Solving Model Forming	Listing possible problem solving models	1.Confirming possible models for problems solving 2.Presenting each problem solving model with Nexpert object
4.Problem Solving Rule Constructing	Rule constructing	1.Constructing quality control rules logincally 2.Organizing problem-solving system
5.System Testing	Checking system function	1.Checking knowledge correctness 2.Checking presentation style 3.Checking function of rule 4.Adjusting unsuitable rule.

Knowledge Acquisition of PQCES

Knowledge acquisition strategies applied in the development of PQCES are accomplished by a series of lengthy interviews between the researchers and several domain experts and through the facts analysis implemented in the printing laboratory of this department, NTNU(National Taiwan Normal University). Both strategies are required for the in-depth understanding of printing troubleshooting. But some jargon words used by domain experts are not easy to transferred into everyday language.

The procedures of knowledge extraction for dot gain variations are depicted in the Fig.4. It consists of five steps as: problem definition, problem analysis, problem solving model forming, problem solving strategy making and knowledge system testing. The contents of the former steps should be adjusted if the results of testing ask for improvement. The major job items in each procedure are listed in the Table.1

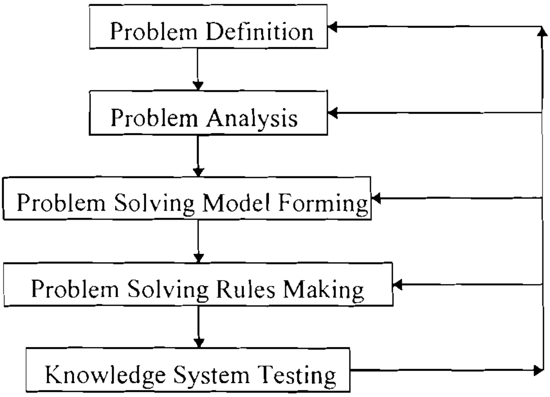


Fig. 4 Knowledge Acquisition Procedure for PQCES

Knowledge Representation of PQCES

1. Knowledge base

The knowledge base of PQCES contains a database and a rule base as stated in Fig.1. For the database, most of the causes of printing troubles are classified into the following categories : 1. Thickness of paper. 2. Speed of press machine. 3. Sequence of color ink. 4. Fountain solution type. 5. Ink type and additives. 6. Tack value of ink. 7. Roller type. 8. Fountain solution quality. 9. Impression. And in rule base, every possible troubleshooting rule was arranged according to the operation model of Nexpert Object. The causes of troubles are written on the left-hand side as conditions and the troubleshooting strategies are listed on the right-hand side as the results of hypothesis testing. The troubleshooting strategy will be represented in the order of possibility if the cause-effect relationship is matched. The knowledge representation flow chart of dot variation related knowledge can be shown in the Fig.5. In which the decision making of every step depends upon the property analysis of that step. And every lower level component becomes a subclass of its direct upper level.

2. Inference Engine

All possible hypotheses should be checked by the inference engine. It is said that all trouble types should be assessed through Forward Chaining or Backward Chaining in the agenda of checking process. If the left-hand side condition is matched, the quality control scale will be triggered and output a proper troubleshooting strategy to the user. The inference engine acts in the rule of "if...then...else..." format.

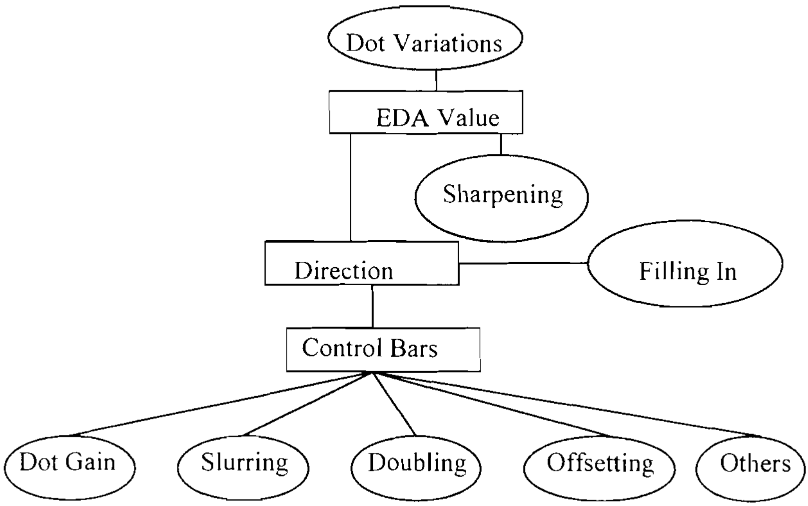


Fig.5 Knowledge Representation of Dot Variations

The framework of inference engine for dot gain variations consists of three parts as the followings:

A. Quality analysis factors
   a. color density of plate
   b. dot variation index
   c. ink overprinting power

d. gray balance control
e. contrast grade
f. others

B. Possible places causing troubles
   a. thickness of paper
   b. speed of press machine
   c. color process sequence
   d. type of fountain solution
   e. ink type and additives
   f. ink deformulating value
   g. roller type
   h. PH value of fountain solution
   i. pressure of press

C. Troubleshooting strategies
   a. adjusting the pressure of plate to rubber blanket
   b. adjusting the pressure of roller
   c. adjusting ink feed speed
   d. adjusting solution feed speed
   e. adjusting the speed of press machine
   f. adjusting alcohol density of lubrication system
   g. adjusting the temperature of cooling system
   h. adjusting the position of form rollers
   i. adjusting the elasticity of rubber blanket
   j. adjusting the surface of rubber blanket
   k. adjusting the tension of rubber blanket
   l. eliminating paper wrinkle
   m. adjusting the ink viscosity
   n. adjusting color process sequence
   o. adjusting paper level

For example,

IF dot gain condition is shown on quality control scale (qualitative analysis)
and EDA(effective dot area) value is increasing (quantitative analysis)
and impression is too heavy
THEN the trouble is "dot gain"
DO check the pressure from plate to rubber
ELSE check the pressure of pressure cylinder
check ink feed speed
check water feed speed
check press speed
check the density of alcohol in damping system

check the position of form rollers
check the elasticity of offset blanket
check the surface of offset blanket
check the surface of plate
check the tension of offset blanket
check the viscosity of ink
check the printing sequence of color

3. User Interface

Several knowledge base editors are used for editing PQCES inference engine. Rule editor, context editor, class editor, object editor, property editor and meta-slot editor are contributed to the construction of PQCES knowledge base. Some other rules, functions, and knowledge base management instructions in Nexpert Object are also applied for knowledge base processing and testing.

Troubleshooting with PQCES

After the accomplishment of knowledge base, user can do the troubleshooting work with Suggest/Volunteer function of Nexpert Object. It consists of three steps as the followings:

The First Step: 1. Input the value of index from the quality control scale of offset printing.
2. Make sure the type of trouble with naked eyes if no scale can be used

The Second Step: The PQCES will browse the nearest inference route with the Browse Rule Network and Session Control object in Nexpert Object package.

The Third Step: 1. The PQCES will display all possible trouble reasons and spots.
2.Troubleshoot the problem spots.

In this prototype of PQCES, dot gain variations are discussed in depth. But its effect depends on the situation of what press and material you use on it. User should answer the following questions shown on the screen of Windows according to the index value of simple printing quality control scale.

1. How is the EDA(effective dot area) value?
   a. increase
   b. decrease
   c. unknown

2. How is the dot value on the quality control scale?
    a. becoming bigger
    b. becoming smaller
    c. slurring
    d. double shadows
3. How is the pressure of press?
    a. heavy
    b. light
    c. unknown
4. How is the feed speed of fountain solution?
    a. too fast
    b. too slow
    c. unknown
5. How is the temperature of fountain solution cooling system?
    a. too high
    b. too low
    c. unknown
6. What is the speed of printing press?
    a. over 10000 rpm.
    b. 8000 ~ 10000 rpm
    c. 6000 ~ 8000 rpm
    d. 4000 ~ 6000 rpm
    e. unknown

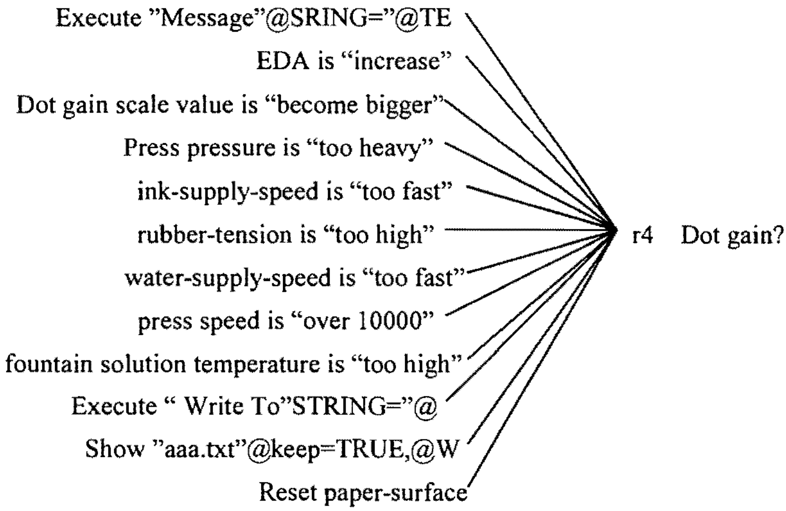


Fig.6 The Rule Net of Nexpert Object for Dot Gain Troubleshooting

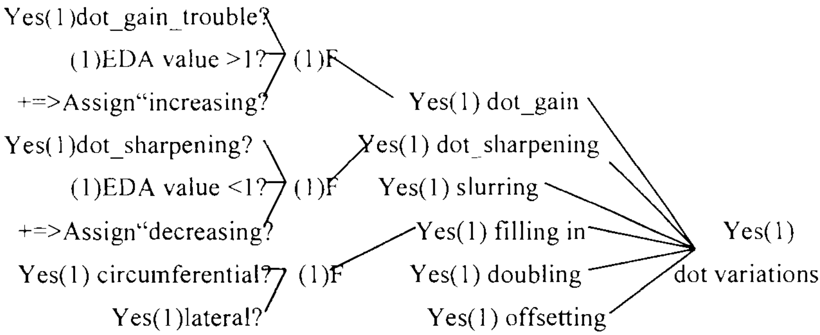


Fig.7 Parts of The Rule Net of Nexpert Object for Dot Variations Troubleshooting

7. How is the tension of rubber blanket?
   a. too high
   b. too low
   c. unknown
8. How is the surface condition of printing paper?
   a. even
   b. uneven
   c. unknown
9. How is the viscosity of ink?
   a. too high
   b. too low
   c. unknown

All answers will be taken as the input of hypotheses in the inference engine. The more information you give to the inference engine, the more precise result you will get. If every thing is unknown, PQCES will give you a possible troubleshooting suggestion instead of correct troubleshooting steps. Since one problem occurred in offset printing may be caused by several reasons, the problem-solving rule may apply the meta-rule strategy. Its judgment logic is followed the Backward Chaining model and is called goal-driven engine. All facts are gathered together to find the defective place. Fig.6 and Fig.7 show the rule net for the dot gain troubleshooting. And Table.2 shows the major troubles and their correspondent troubleshooting strategies of dot gain problem.

Table.2 Troubleshooting Strategy for Dot Variations

Possible ways: Adjusting	Dot Gain or Sharpening	Doubling	Slurring
1. the pressure of plate to rubber blanket	*		*
2. the pressure of roller	*		*
3. the ink feed speed	*		*
4. the solution feed speed	*		*
5. the speed of the press machine	*		
6. alcohol density of lubrication	*		
7.the temperature of cooling system	*		*
8.the register position from rollers	*		
9.the elasticity of rubber blanket	*		*
10.the surface of rubber blanket	*		*
11.the tension of rubber blanket	*	*	*
12.eliminating paper wrinkle		*	
13.the ink viscosity	*		*
14.color process sequence	*		
15.paper level		*	*
16.the surface of printing plate	*		

Experimental Results and Discussions

The proposed PQCES system has been tested for demonstrating the advantages of expert system based training system for offset printing troubleshooting. It is found that the rule-based problem-solving strategy can reduce the learning time span. For dot gain and dot variations troubleshooting, a senior undergraduate student major in printing can make correct decision to deal with such problems no longer than an experienced skill-worker did after learning with PQCES. Traditional printing troubleshooting with naked eyes and experienced brain will be faced with the challenge of computer-based training. But there still have some difficulties to be conquered in this PQCES prototype expert system as the followings:

1. The uncertainty of judging the causes of troubles with heuristic method make troubleshooting results uncertain in some cases such as the difference of plate type, press machine, or paper quality...etc.
2. The complexity of decision-making in troubleshooting make

forward chaining and backward chaining conflict in some cases such as the unbalance of water and ink may cause several syndromes, and one syndrome may be made from several causes.

3. Some domain experts insist that their judgment about dot variations is absolutely correct even if other experts have different opinion. It makes knowledge acquisition and representation more difficult. How to represent human experts' subjective idea with objective rule is a more basic problem in developing an expert system for complex printing technique.
4. The GUI design tool provided by Nexpert Object package 3.0 is applicable for design graphical elements and window level, but it can not merge an image transferred from a scanner or a CCD camera. If the image database of trouble phenomena can be used cooperatively, the effectiveness of PQCES will be enhanced.
5. The capacity and function of PQCES depends largely on the performance of Nexpert Object package. Its simple inference engine control logic make knowledge base constructed with almost the same expression as "if..then..do..else..". for troubleshooting. The simplification of printing quality control can be reached with expert system based training system.

Conclusions

The development of PQCES and its application in the field of offset printing trouble- shooting has been proved feasible even though it still has some deficiencies in the whole system. The structured decision-making logic has made troubleshooting simple and efficient for dealing with the offset printing troubles. Several conclusions were drawn from the PQCES development as the followings:

1. The dot variation is the major cause of bad quality in offset printing. There are seven phenomena classified into this trouble including dot gain, sharpening, filling in, slurring, doubling, offsetting and deforming. Traditional quality control and troubleshooting for these syndromes depend on the experienced skill-worker with their naked eyes and some scales. But the uncertainty of human factor, material factor, and process factor may influence the validity of quality control. The availability of expert system will reduce the uncertainty of decision-making in printing quality control.

2. The knowledge collected by interviewing the domain experts and developed with generic rules provided by Nexpert Object made knowledge base more applicable than a specific human expert. In

this step, PQCES worked like an expert offering cognitive training to entry-level printing workers. Besides, it can be used to improve the printing quality control for incumbent quality control workers.

3. Traditional scale reading method support user with "know what" or "know when", but PQCES support user with "know how". User not only know the scale value, but also know the reason why it comes and how to troubleshoot it.

4. As a prototype of quality control expert system for dot variations, the inference engine performs the major role for troubleshooting decision-making. The rule of "if..(1) and (2)..then...do...else..." made complex relationship between right-hand side and left-hand side conditions simplified. The main purpose of PQCES can be reached in the process of simplification of troubleshooting the dot variations.

5. For the further research, a real time quality control system which integrates the printing machine and a microcomputer with automatic instruments can be developed for advanced color printing quality control. The expert system will be designed with the upgrade version of Nexpert Object package.

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References

Barry, G. S.
1990, "Critiquing human judgment using knowledge acquisition systems", AI Magazine, summer, pp.60-79.

Chen, C. L.
1993, "Web sized offset printing technique", Chinese Culture University Press, Taipei, pp.299-312.

Chuang, C. P.
1995, "A Color Vision Application On Resistor Color Code Interpretation", 4th IASTED International Conference, pp.117~120.

Groff, P J.
1991, "GATF glossary of graphic arts terms", GATF, Pittsburgh, USA.

Hohman, J., & Nagee, B.
1987, "Instruments for the graphic arts", GATF, Pittsburgh, Pensylvania, USA, p163.

Honjo, S., Taguchi, S., & Suzuki, T.
1989, "Dot gain in halftone images", SPIE, Vol.1184, pp.43-47.

Hsu, P. A.
1990, "Knowledge engineering and expert system", Song-Kang Publishing Co. Taipei.

Huntsman, J. R.
1991, "A simple alternative to the Neugebauer equations for computing dot area and dot gain colorimetrically", TAGA Proceedings, pp.173-195.

Huang, I. W.
1990, "An expert system for creative structure design". Ph.D. dissertation, National Cherng-Kung University, Tainan, Taiwan. pp.106-119.

Huang, M. C.
1993, "The influence of dot gain to color reproduction", master thesis, Graduate Institute of Printing Industry, Chinese Culture University. Taipei, Taiwan.

Jackson, P.
1991, "Introduction to expert systems", 2nd ed. McDonnell Douglas Research Laboratories, Saint Louis, Missouri, Addison-Wesley Publishing Co.

Janet, L. K.
1991, "Improving human decision making through case-based decision aiding", AI Magazine, summer, pp.52-68.

John, F. S.
1984, "Conceptual structures: Information processing in mind and machine", IBM Systems Research Institute, pp.277-298.

John, S. G.
1990, "Design Prototypes: a knowledge representation scheme for design", AI Magazine, winter, pp.27-36.

Lee, S. T., & Lo, F. L.
1992 "Introduction to printing industry", Research Institute of Chinese Printing, Chinese Culture University Press.

Wang, M. D.
1993. "Nexpert Object and smart applications", 4th Nexpert Object user group meeting , Taipei, Taiwan.