THE DETERMINATION OF PRINTING PRESS IMPOSITION BY MEANS OF ARTIFICIAL INTELLIGENCE TECHNOLOGIES

BY
MORTON S. BALBAN*
AND
MING-SHONG LAN AND RODNEY M. PANOS**

ABSTRACT

The positioning of printing plates on a press, or imposition, is a complex process, basic to the printing operation. It requires knowledge spanning equipment and process usage, as well as operational rules and procedures. Obtaining this expertise involves the study of a wide range of disciplines and encompasses, often, years of apprenticeship. It is, furthermore, becoming increasingly complex as technology helps produce larger and higher quality newspaper products.

Rockwell International's Graphic Systems Division has investigated Artificial Intelligence technology to determine whether its application could assist in this process, and to make more readily available and timely the wide-range of specialized knowledge needed. Rockwell has designed and implemented an Expert System, The Press Lineup Advisor © , that configures the plate locations for multi-web printing presses. This system is currently being field tested by the Los Angeles Times. These tests show that correct impositions, which are used in actual printing operations, are produced by the Advisor.

INTRODUCTION

Printing operations require the proper selection, setting and interaction of various materials and processes, coupled with the consideration of a host of physical and operational constraints. Modern printing equipment can produce newspapers of high visual quality

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* Graphic Systems Division - Rockwell International
Chicago, IL. 60650
** Science Center - Rockwell International
Thousand Oaks, CA. 91360

at rates exceeding 70,000 copies/hour. Once the printing presses are started, the pages are printed, sectioned and folded automatically into completed newspapers.

The lineup, or imposition, of a newspaper's printing plates is intrinsic to the production of the printed product. An imposition, the proper placement of each printing plate on the press so as to produce a newspaper product with the desired section and page sequences, is often necessary several times daily. The difficulty of its design, in each instance, depends on the product's size/content, advertisements, editions and geographic distribution. Since the imposition is integral with the printing operation, changes in the product requires a new/modified lineup. Furthermore, the available reaction time to accomplish it is often short, as changes in newspaper content are being made increasingly closer to press operation deadlines due to rapid news availability, advertisement additions or changes and/or edition management needs.

Press lineup design calls for considerable expertise in both equipment usage/detail and in operational rules/procedures of the various departments and functions of the newspaper. The necessary background often requires years to obtain. Therefore, few people have the requisite experience. In addition, as newspaper needs and implementations change vis-a-vis color content, advertisement cutoff times, edition structure, and remote printing sites, the need for such experts is increasing.

The timely availability of a lineup expert is often crucial to meeting the various operational and advertising requirements of a modern newspaper and to its proper and efficient production.

PROBLEM SCOPE

Press imposition/lineup determination is not a simple procedure. Consider, initially, the press configuration itself. Figure 1 shows the outline of a typical printing press. This example shows five units; two with color half-decks and one containing a full color deck; a

folder and nests of angle bars for turning and routing the paper web. Figure 2 illustrates an approach often used for splitting the web and routing each portion separately by means of an angle bar. The reader can see that with the various press configuration variables; which include the number of press units with color half and full decks and the relative placement of each; which are coupled, furthermore, with factors such as the printing mode of operation, use of angle bars, slitters, etc., etc.; that the number of routing possibilities that may occur are extremely large. And these variables are only the physical configuration options.

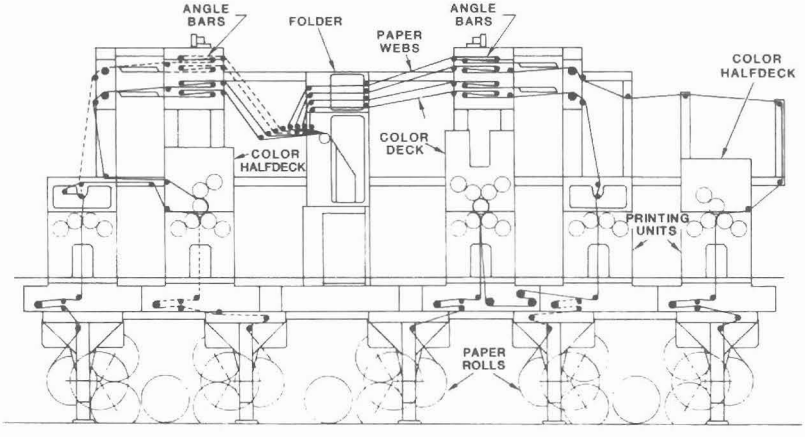

FIGURE 1- TYPICAL PRINTING PRESS

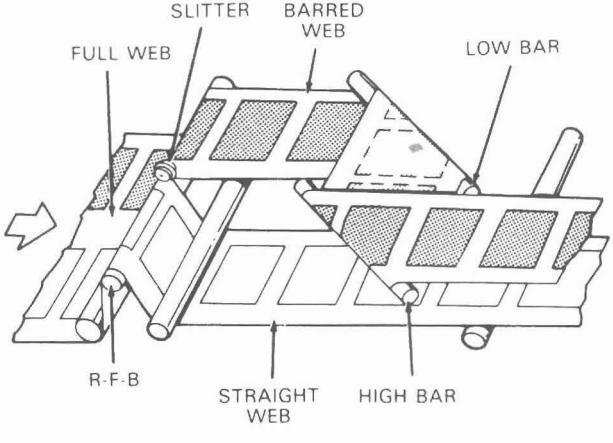

FIGURE 2- WEB ROUTING

Product related factors must also be considered. These include the number of, and quantity of pages for each of, the newspaper sections, number and types of color pages, advertiser requirements and, of course, a wide spectrum of the publishers operational rules and conditions.

The imposition problem is made even more complex by its sheer magnitude. As shown in Figure 1 some units can print color and some cannot. Each unit has a paper web passing through it (and there can be 12 or more units per press). A web can have up to 8 or 16 pages, depending on Straight or Collect mode of operation, printed on it. The newspaper publisher can, and often does, print more than 100 pages in an edition. In fact, our Goss Imperial 3:2 folder can handle 160 pages at a time.

No general algorithms are available for configuring a press. Variations in lineup possibilities are so large due to specific product requirements, maintenance needs, press configurations, previous and future run conditions, advertisement needs, operational constraints, etc., as mentioned above, that look-up tables cannot be realistically devised. Based on all of the above, a given product may have

a) no possible lineup
b) only one possible lineup, or
c) more than one possible lineup

Therefore, the reasonable and realistic approach to the configuration task is to "construct" an appropriate lineup. This construction is usually done by the newspapers' lineup expert. If the experts' knowledge can be characterized and stored then, it was felt, the construction process might be assisted, expedited or even automatically performed. Artificial Intelligence technology offers the potential for devising and implementing systems to help address the imposition design challenge.

ARTIFICIAL INTELLIGENCE/EXPERT SYSTEMS (AI/ES)

During the past several years, Artificial Intelligence (AI) technology has emerged from the university laboratory into the real world marketplace. Its prime subset, Expert Systems (ES), has increasingly been successfully implemented in a broad scope of applications ranging from oil/mineral exploration, to computer configuration, to medical diagnostics, to equipment maintenance, as examples. All of the applications have the common thread of being based on the expertise of specialists. The expertise is very often obtained only after a long apprenticeship that requires years of hands-on experience. These systems have not been generally used to supplant the expert, but rather to assist in making the associated operations less tedious, and often more thorough and consistent; and to provide a means to more easily and quickly disseminate the expert information to those needing the knowledge.

Expert System shells have become available during the past five years. These shells, although designed around the various classic programming languages such as PROLOG, LISP and C, have permitted a class of designers known as Knowledge Engineers, to evolve. These shells allow the Knowledge Engineer to concentrate on obtaining the necessary expert knowledge, characterize and format it, design the logic flow and then design it (with the proper conventions and syntax) into the expert system. Programming with basic computer languages still can be used instead of the shells but are not as efficient nor produce a usuable system as quickly. The application expertise obtained via topic research, analysis and interviews with experts is "translated" into a Knowledge-Base (KB), which forms the brain of the Expert System (ES).

Expert Systems differ from typical computer programs in several major areas. They are object/concept oriented rather than procedural/sequential in operation. They function symbolically and seek plausible answers by employing knowledge/rule bases in a heuristic fashion. The ES seeks, or infers, logical answers based on available knowledge and the emulated thought process, rather than considering every possible numerical path or

possibility. A shell consists of three sub-systems - a natural language input/output facility for easy access to the shell logic and Knowledge-Base (KB), a KB to provide the "facts" for the ES to use and an "Inference Engine" to accept input information, analyze it and compare it to the KB, and manipulate it according to the control processes designed into the ES. It then provides the requisite output response. The expert system attempts to operate as a human might in reaching a conclusion.

A priori established Rule, Object, Symbol, Attribute, Control Block, etc. forms are integrally provided within the transparent expert system shell. Although the expertise "translation" must be thoroughly planned, and certain protocols observed, classic programming is not required. Figure 3 illustrates an actual Rule form, "programmed" for use in the Press Lineup Advisor, showing the categories that the Knowledge Engineer fills in, or programs. Many Rules, as well as the other shell forms, are used in a given application. Each of the other shell items listed above has its appropriate format to be programmed by the designer.

```
DEFINE RULE      LARGE.COLOR.PRINTABLE.010
::APPLIED.TO       i:imposition
::PREMISE          already.existing(s1:section, s2:section |
                    section.number[s1] = off.side.front.section[i] and
                    section.number[s2] = main.side.front.section[i] and
                   off.side.front.has.color[i] and
                    main.side.front.has.color[i] and
                    for.all.existing(cp1:color.page | part.of[s1,cp1])
                     page.number[cp1] = 1 or page.number[cp1] = last.page[s1] and
                     for.all.existing(cp2:color.page | part.of[s2,cp2])
                     page.number[cp2] = 1 or page.number[cp2] = last.page[s2])
::CONCLUSION       begin
                    first.color.printability.check.for.large[i];
                    large.color.imposition.technique[i] = simple.scheme;
                   end
::CATEGORIES       {large.color.printable.rules}
```

FIGURE 3- TYPICAL RULE FOR CONDITION COMPARISON

Figure 4 shows a simplified logic flow diagram used to plan/design the actual Press Lineup Advisor expert system. The actual diagram entails many pages of function/logic interactions. This design aspect and the extraction and interpretation of the experts "knowledge" in the domain of interest (application) form the crux of the expert system development. The shell permits these prime knowledge engineering activities and application requirements to be more effectively concentrated upon.

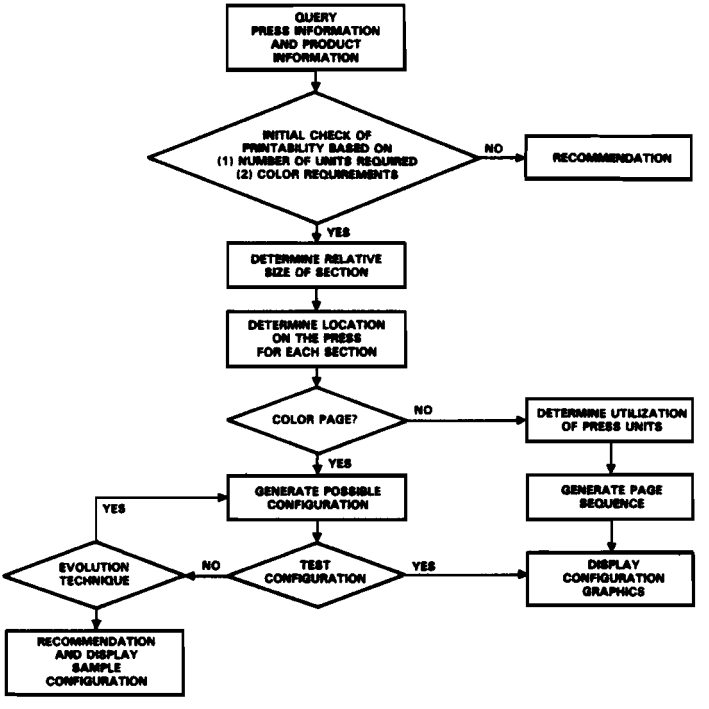

FIGURE 4- LOGIC FLOW DIAGRAM

PROBLEM-SOLVING APPROACH

The task of determining an appropriate printing press configuration can be considered to be one of utilization of available elements. However, "available elements" is a complex inter-relationship of physical "hard constraints" having to do with press units/half units, etc. and somewhat flexible, but "soft" constraints; i.e. minimization of number of units used, minimization of special web routing techniques (angle bars, split leads,

partial paper rolls); balanced operation to help reduce vibration and web breaks, and varying requirements from outside sources such as MIS and control systems. Furthermore, these vary from user to user and may even change for a given user for his different sites or conditions.

Two major problem solving approaches are used to address press imposition requirements. Product configurations exist which can be handled using expert system methods which rely upon, and infer from, the various rules derived from the experts, relating to the hard/soft constraints. Other product requirements exist, however, which may present either conflicting press utilizations or require a "review" of lineup alternatives in order to best meet the product needs.

The problem-solving methods are:

1. Rule-based methods
2. Generate-and-test methods

For a newspaper product which does not contain color pages or with color used only on the front and the back pages, a rule-based approach is used. In this case, the rules and procedures to configure a press that are normally used by the imposition experts are implemented in the expert system via the explicit-control modules (Control Blocks within the ES). The judgemental knowledge expressed in system rules is used to check whether the desired newspaper is possible to produce and, if so, to determine how each press unit is to be utilized. The heuristics and reasoning process encoded in the System leads to a near-optimum lineup without requiring a generate-and-test approach. This rule-based approach, furthermore, allows incremental knowledge growth and/or change via the addition/deletion/ modification of the individual rules. Figure 3 shows an example of a rule of this type. Configuring a press to print products with interior color pages within a section is not as straight-forward, however. A generate-and-test method is required in conjunction with the rule-based method. However, exploring several hypotheses until an acceptable one is found, is avoided. The System first generates a possible lineup by assuming the newspaper has no color pages or has

color pages only on the front and the back pages. Then it will test whether the proper color pages are on the suitable positions on the color units. If not, instead of randomly generating another lineup, it will determine whether any means can be used to evolve the current result into an operationally acceptable lineup; or the system will recommend a possible change to the product so that an acceptable lineup can be designed and outputed. This involves changing the utilization of press units and the generation of an new hypothesized lineup. Figure 5 shows an example of a generate-and-test Control Block used in the system. It can also determine; for example, for cases where color printing units are not available to print the desired color pages with the page numbers assigned, and also meet the other product requirements; suggested change(s) in page sequence to produce an acceptable imposition.

```
/********************************* GENERATE AND TEST *********************************/

    repeat
        if already.existing(i:imposition | current.imposition(i))
            then
                begin
                    if already.existing(bu:back.unit, fu:front.unit | current.back.unit(bu)
                                                                    and current.front.unit(fu))
                        then
                            invoke generate.imposition.for.large.color(pr,bu,fu,i,p);
                    invoke test.imposition(i);
                    if not printability.for.large.sections.based.on.lineup[i]
                        then
                            begin
                                invoke seek.alternative(i);
                                if evolution.technique[i] ~= none
                                    then
                                        invoke setup.for.new.imposition(i,p);
                            end;
    until already.existing(i:imposition | current.imposition(i) and
                                (printability.for.large.sections.based.on.lineup[i] or
                                evolution.technique[i] = none))

/*********************************************** END ***********************************************/
```

FIGURE 5- GENERATE-AND-TEST CONTROL BLOCK

THE PRESS LINEUP ADVISOR ©

The Press Lineup Advisor is designed around an expert system shell, Teknowledge's S.1. The S.1 shell provides a means to represent the imposition knowledge (rules, procedures, utilization options), a control scheme and an inference engine which accepts the input requirements and manipulates the rules via the control blocks designed by the Knowledge Engineer. It provides, furthermore, an explanation facility which aids in the design/debugging process and also alerts the user to any input discrepancies. An input/output (I/O) user interface is integral in the shell. A Xerox 1109 LISP workstation was used for the development work. This computer provides excellent graphic capabilities and a user friendly operating system and I/O facility.

Facts (rules, constraints, tests) relating to the imposition procedures, are stored as object-attribute-value triplets with associated confidence factors. Control of the reasoning process is facilitated by Control Blocks. A Control Block is an explicit procedural statement of how the "reasoning" process is to proceed. That is, problem-solving strategies are expressed in procedural control blocks and judgemental knowledge is expressed in the form of rules. The primary advantage in separating declarative from procedural knowledge is that the knowledge-based system becomes more modular, maintainable, and transparent.

The Control Block emulates the thought processes' approach, i.e. do this first, then do the second thing, etc. It determines what user information is needed and then how this information is to be used (compared to rules, ask other questions, etc.). The Attributes, or characteristics of the main objects are consulted during the imposition construction process.

The background knowledge, and lineup design criteria and procedures, were obtained by means of a series of interviews with press lineup experts and through study of a broad variety of actual lineup examples provided by these experts. A series of iterative interview-design-test-demonstration-interview sessions was used to design/refine the knowledge base.

Since an expert system uses symbolic object orientation in its "programming" rather than numerical/sequential approaches, it is important to properly select and characterize the main elements necessary to the construction or reasoning process. For the Press Lineup Advisor, eleven classes of objects are defined. These are: Press, Back Unit, Front Unit, Section, Press Run, Color Page, Imposition, Near Location, Near-Center Location, Far-Center Location, Far Location. Various Attributes are associated with these and other press/product aspects. These are acted upon by rules via Control Blocks. For the twelve unit double-width printing press considered here, six units are in front of the folder and six units are in back of the folder. The press layout identification is basically generic so that different user press configurations, either for a given user or for another publisher, can be easily changed/accommodated. For this case, the "press world" is composed of six instances of Front Unit and six instances of Back Unit with different press unit names. Furthermore, each press unit is divided into four locations which are represented by the four location object classes (see above).

To configure a press, the System uses the requisite Control Blocks, Rules and Attributes for each "Thought Process". It first determines what portion of the press (main side, off side, front side and back side) is used for a particular section of newspaper, based on the total number of sections, the section number and the page content of each section. Then it will determine the utilization of each press unit. Utilization is one of the Attributes defined on Front Unit and Back Unit. In configuring a multi-unit press, the value of a unit's utilization can be none, full, main half, off half, main three quarters or off three quarters.

Thus the system has to reason among multiple instances of multiple classes. This further shows that a sequential look-up table approach or pre-determined algorithms, would not be effective.

The Press Lineup Advisor therefore constructs an imposition, compares it against the various rules/constraints and performs internal generate-and-test procedures, if necessary, to verify that an

imposition is possible and does indeed meet the user product and operational requirements. If it does not, then the Advisor generates another instance of imposition and tests it. Although there is only one printing press; "press worlds" are generated and tested. Boolean Attributes such as Front.Unit.Forgotten and Back.Unit. Forgotten are defined so that if a press-world fails to meet the requirements, values of old instances do not have to be "reasoned" again. In addition, functions such as Current.Imposition, Current.Front.Unit and Current.Back.Unit are defined and considered, as required.

Three versions of the Press Lineup Advisor have been designed and tested. This approach was utilized so as to properly define knowledge/problem domains to be addressed by the AI/ES techniques. This is important so that a bounded knowledge-base can be designed and properly tested. Once a domain is successfully addressed, it can be expanded and/or "attached" to another, etc. so as to create the overall expert system which addresses the applications' total requirements and the knowledge (procedures/process, etc.) areas/aspects that are of interest. In this development program version 1.1 considered black/white newspapers; Version 2.0 added color product requirements, increased I/O capability and expanded graphical output represention; and Version 2.1, which is currently installed and undergoing field testing, adds Collect and Split-Section operation.

SYSTEM PERFORMANCE

A series of questions, a consultation, is presented to the user on the system's CRT screen. The Press Lineup Advisor thereby determines the physical status of the press, and the printed products' characteristics (sections, number of pages, color pages, advertiser names, etc.) based on the users' answers. The system then analyzes this information and goes through the reasoning process described above. An imposition will be constructed and graphically displayed within 45 seconds to 2-1/2 minutes (running in LISP) depending on the products' configuration. The imposition displayed can be easily transmitted, via RS232C lines, to other user's departments or plants, MIS, etc. and/or hard copies made, as needed.

For the current versions based on the knowledge base derived from the Los Angeles Times experts, the Times' Pressroom Make-up Form is emulated. It is identical to the form used for their newpspaper impositions, with the addition of the Rockwell logo. Any users' form can be modelled. Figure 6 shows a lineup produced by the Press Lineup Advisor for a 4-section newspaper containing several color pages. Each horizontal line represents a press unit. Roman numerals indicate section numbers, while Arabic numerals show page numbers. Ripples show portions of press units not used. The "X" on the unit line indicates color page location. Arrows across the center of the section line show where angle bars are used. A large "X" in the middle of a section line indicates that a split lead is used there. The lighter weight lines, with and without arrows, show whether an upper or lower former of the folder is used for the paper web leads of a particular section.

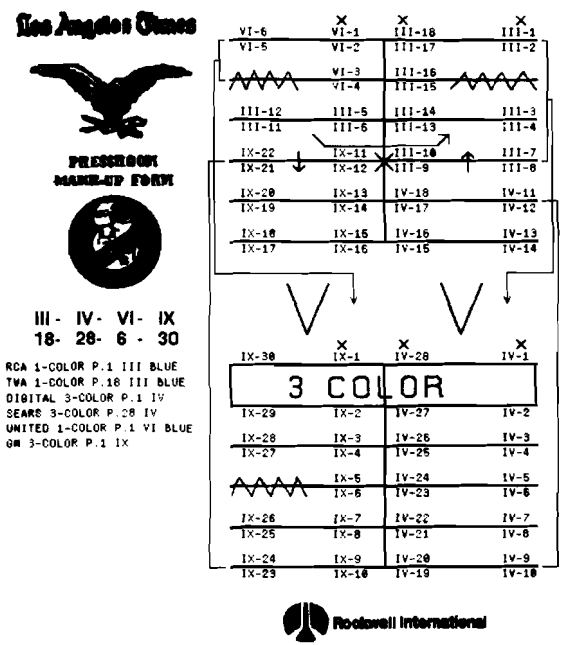

FIGURE 6- PRESS LINEUP ADVISOR OUTPUT PRESENTATION

Version 2.1 of the Press Lineup Advisor, based on the operation of the Los Angeles Times, is currently undergoing field testing at a Times' publishing plant. Results of tests on Versions 1.1 and 2.0 have produced lineups that are accurate and have been implemented on the presses.

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