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SYNTHESIS REPORT

PROJECT No : CR-1210-91
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STARTING DATE : January 1994 DURATION : 24 months

TITLE : SHEET-FED OFFSET **TRAINING** SIMULATOR (**SHOTS**)

PROJECT COORDINATOR : Peter HERMAN

PROPOSERS :
Aldens (UK)
BASF (K+E) (UK)
Berkshire Printing (UK)
Blackmore Press (UK)
Britannia Labels (UK)
British Printing Industries Federation (UK)
Brunei College (UK)
Butler & Tanner (UK)
Cefograf (B)
C.F.T. Gobelins (F)
Day International (UK)
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Man Roland (G)
S.B.O. (GOC) (NL)
Leicester South Fields College (UK)
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R&D PERFORMERS :
Sinapse (F)
NPSC (Uk)

FOR THE PERIOD FROM : 01 01 94
day month year

TO: 31 12 95
day month year

PROJECT FUNDED BY THE COMMISSION OF THE EUROPEAN COMMUNITIES UNDER THE CRAFT ACTION OF THE BRITE - EURAM PROGRAMME

SHOTS : SHeetfed Offset Training Simulator

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The goal of the SHOTS project was to build a generic model of the offset printing process, and to embody this model in a simulator. The simulator was to be used to validate the model and to help those in the industry to better understand the process, its variables and its functional dependencies. It was felt that better trained personnel would be able to adapt to change more easily, as well as being more productive.

The simulator that was built models the offset process as it applies to sheetfed printing. This is the largest segment of the printing industry with over 80000 companies involved in this sector in Europe alone. This industry represents well over 1 000000 jobs in the European Union.

While the simulator represents the short-term results, the real long-term benefit from this project is the underlying model of the process. It can be applied to process control for the offset sector as well as serving as a base for similar models for other sectors of the printing industry. As the industry evolves, the underlying model can be used to keep the simulators updated so that existing personnel can adapt to the new technology and new personnel can learn how to operate the process. The underlying model is a generic one - serving the interests of the group of SMES in the project, and not reflecting any one supplier's technology.

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Contents

Introduction

This was in many ways a non-standard research project. The printing industry is still very "craft''- oriented, and the domain was not well formalised. It was necessary to model people's knowledge and behavior as well as formalizing the more technical process constraints. We will describe below the context in which the project was developed and what some of the motivations and problems were.

Project History

The project was initiated at the demand of the British Printing Industry Federation. They had been aware of other developments in simulation for the printing industry, and wanted to see what could be done for their smaller members. For these members, the co-operative research project had to produce concrete results within its lifetime.

For this reason, the simulator was a good way of both showing that the underlying model was correct, and giving the SMES results they could use immediately for training.

Their primary objective was to move training for this industry out of the apprenticeship mode *(do as I do)* and into a process and quality control approach. This approach reduces the amount of time necessary to train leading operators, and improves the overall quality of plant personnel. The resulting tool (training simulator with exercise generator, and diagnostic help system) helps its users to rethink their training strategies and to better define whom they are training, and what they want their personnel to know. The tool helps process operators acquire a ***structured problem-solving approach to quality control.***

The end result is thus an example of what is increasingly called IPS (Integrated Process Support); intelligent, interactive tools that are useful for both training and diagnostic help.

The project results are thus of two types : formalisation of process, materials and diagnostic expertise, and the production of a series of prototypes of the IPS tool mentioned above.

Motivation for the Participants

Better trained personnel mean less down-time, quicker job preparation% higher quality. These are all competitive advantages in a very fast-moving market. The project results are also immediately applicable to countries with no existing infra-structure for technical training, or whose training and working methods are outdated.

The primary motivations were thus to complement any existing apprenticeship programs and to reduce training costs be a minimum of 4 KECU per employee.

The advantages are those commonly associated with better trained personal and shorter training times.

- Lower training cost (see below)
- Less attrition among candidates
- Greater depth of competence among the personnel (more flexibility)
- Less waste and shorter make-ready, which mean lower costs and greater productivity which, in turn, mean increased competitiveness.
- Better quality output which means increased customer satisfaction and repeat business.

It should be noted that environmental imperatives are radically modifying the way printers work, in particular the types of raw materials they use. The new inks and varnishes, for example, use less harmful solvents and are easier to recycle, but have different characteristics and react differently to the other elements of the process (ex. recycled papers). If the printers are to stay competitive, they must learn to adapt their processes and practices to best integrate these new imperatives. The SHOTS approach gives the process operators a better level of understanding, which will make it easier to adapt to these changes.

Within industry there was no current way to train sheet-fed printers other than on the press itself This is costly and potentially dangerous for the person and the equipment. It is a slow and inefficient method of training which tends to concentrate on machine manipulations rather than on quality control methods. It is not feasible to destabilize the process or to damage the machine just to illustrate to the trainee what happens. Nor is it practical to run the same "problem" over and over on the press until it is understood. The role of the simulator is thus clear ; it is a way of <u>showing</u> trainees what one could only <u>tell</u> them otherwise. It is intended to put them in situations where they are confronted with unexpected problems and must solve them by thinking for themselves, This is now conventional wisdom in the aerospace and nuclear power domains, but has yet to spread to smaller, less high-tech industries who could nonetheless benefit from the approach.

Such a product also has a strong potential in less-developed countries or countries whose industrial base has become outdated (e.g. Eastern Europe). While it is comparatively easy to install new plant and equipment, it is considerably more difficult to retrain people to more modern working methods. A training simulator, built from the beginning to be multi-lingual, is an excellent way of overcoming this hurdle.

It currently takes a minimum of two years to train a printer. This costs at least 15 000 ECU (British Printing Industry Federation). It is estimated that the SHOTS results will reduce this by 25°/0 : it will provide away of getting equal competence in a shorter time and with less training cost, and increased competence within the same two year period.

Project Partner Group

In order to build the expert models of offset technology, fault detection and diagnostics , a broad-based group of partners was assembled. This included over a dozen printers (mostly from the UK, and most with under 100 employees).

The group also included suppliers to the printing industry. These were made up of MAN Roland, a German printing machine manufacturer; BASF, who supply inks and fountain solution and DAY International, who specialise in image transfer mechanisms (blankets). Print Industry Federations from France, Belgium and the UK were also part of the group, as were training organisations from France, the UK, Belgium and the Netherlands.

The wide range of partners made it possible to have both a model-driven and a data-driven approach to the problem. The suppliers provide a model-based (top down) approach to the process and the theoretical interaction of its components. The printers, on the other hand, have a hands-on, data-driven (bottom-up) approach that starts with the process output . The suppliers try to define conditions for their particular parts of the process so that nothing should go wrong. The printers start with the fact that things are going wrong and have to work back to the potential cause(s).

To put in another way, the suppliers have knowledge on what the process *should do,* and the printers are experts in what it *does.*

The emphasis was always on the printers, as they were the SME driving force behind this project, and they are the primary market for its end product.

The main R & D contractor for this project was a French company called Sinapse. They are specialised in training simulators and in diagnostic expert systems for industry. One of the reasons they were selected was that they also had prior experience in doing modelling of the printing industry.

Historical perspective and state of the art

There were no existing products in this area. The results in Web simulation(high speed print process) were not applicable, since the sheetfed process is very different in the types of materials and the colour reproduction techniques.

The prior work on sheet-fed simulation was all from a process engineer's point of view and was of no direct use to the printers. Understanding the quantitative equation for varnish bonding to ink is good for the chemical engineers, but will not train the printer to recognise or react to the problem he has with the sheets sticking together. In sum, existing models were incomplete (focus on one aspect of the process), primarily research-oriented, and of little or no use to the printers themselves.

Prior work in related areas has been carried out by the Finnish research laboratory VTT (in the Printsim project) and by the French research consortium GIR. In both cases, results have been obtained, but only for the rotary press sector. These results are only partially applicable to the much larger sheet-fed market. The rotary sector uses rolls of paper which are continuously spliced together. This implies a much higher-speed process, a narrower, more normalised range of raw materials, and cm-line conversion techniques (folding, cutting, finishing, binding,...) which set their problems apart from those of their sheet-fed colleagues. Sinapse, the main R & D contractor in the SHOTS project, was chosen by the consortium for its experience with the French GIR.

The SHOTS consortium considered that the sheetfed and web process models are different - in particular concerning the raw materials such as film, cardboard, and varnish, and process differences such as W drying and “process VS. pantone" color. - and that existing results were not applicable to the problem at hand. It should be emphasised that in any case the solutions from the rotary project were far too expensive for the sheet-fed sector. Existing simulators also necessitated high-end hardware for numerical calculation and four-color displays ; SHOTS developed new technology to use oil-the-shelf components and build a low-cost easy to use product.

As an example, the specialised graphics hardware (separate from the computer) used in one of these projects costs as much as the total hardware configuration targeted for the SHOTS project; SME's don’t have the same budgets as the multinational printing groups.

Technical Description

Analysis

The order of the tasks described below is roughly their sequence in the project lifetime; Analysis was before Development, and the Overall Architecture was defined before the Formal Data Base. However, much of the basic data gathering and normalisation was done in parallel with the more formal conceptual analysis. As the project only had a two-year lifetime, it was necessary to start gathering data as soon as the project started.

At the initial project meeting (February 94) a set of worksheets was distributed to all partners, and they were requested to start assembling fault libraries. These fault libraries were composed of samples of process output which had quality problems. These libraries became the starting point for the "data-driven" analysis mentioned above.

The worksheets covered the visual aspects of the "print faults" as well as going into detail on underlying causes and possible solutions. The information at this stage was primarily qualitative. For example, one of the questions concerned the temporal development of the process problems. Does *it get worse as time goes on?*
The possible angers were: Yes, *No, Depends on (machine speed, raw materials, ...)*

Later in the project this qualitative data was refined (where possible) into scenarios which asked the participants to put specific coefficients on the way things got worse and the time flames in which this could happen.

A second set of worksheets focused on the model-driven approach. It defined "process-problems", their causes, effects, and evolution over time, and linked these to the various components (mechanical or material) of the process.

The twin approach, model and data-driven, meant that each one acted as a coherence and completude check on the other. Effects defined in the model driven approach had to exist among the print faults described in the data-driven approach. Causes described in the data-driven approach had to be linked to process problems from the model-driven side.

Generic Model of Printing Machine(s)

The first task was to get consensus within the group on what should be modelled. The idea was to model those parts of the process that underlie the majority of the existing sheetfed presses (probably over a million presses world-wide). The easiest way to get agreement was to define a generic press.

Mechanical Elements

Defining a generic press meant specifying the types of components and their topology (the physical and functional relations between them). While the heart of a printing press is the printing unit, the input and output devices are also very important as they must be adapted to different types of paper. The settings are not the same when printing frozen food cartons as when printing year-end reports or bibles.

In addition the control functions must be defined and any other manipulation or intermediate treatment. For example the paper sheet is often turned over during the printing process to print on both sides, this can lead to problems of ink coming. off on parts of the press which will lead to color pollution in subsequent images. Another example is the use of coatings (water-based or UV in nature) to highlight parts of the printed image, and the drying techniques (hot air, Infra Red or Ultra Violet) which must be adapted to the type of coating.

Raw Materials

It took a a great deal of time to define a representative set of raw materials to model. As work habits (and units of measure) vary between countries, it was necessary to include seven different types of paper and cardboard.

There are also two types of ink, two types of coating, and several possibilities for the image carriers (plates).

Environmental Variables

The environmental variables primarily concern the ambient heat and humidity in the work environment.

Functional Description of Simulator - Non Technical

The next step was to agree on the results that the users wanted from the project. This was focused on the functions of the simulator: what it could show, how it could be validated, how it could be used for training and trouble-shooting.

This reassured the SME's about what they were going to get for the money they were paying.

Fault List and Dictionary

The fault libraries mentioned above were analysed. Their contents were classified and given names. A first set of causal links was established between the print fault (the process output) and the underlying process problem.

Initially there were about 60 print faults, about 150 process problem and about 450 cause/effect pairs.

As the project progressed the definitions became finer grained, and at last count there were about 100 print faults, about 200 process problems and about 600 cause/effect pairs. Data bases were created to store this information.

Print Faults Attribute Grammar and Validation Method

A descriptive grammar was developed for these faults. This served initially to determine what common visual traits they shared. This information was used to build the simulator module (see CopyDesk below) that "prints" the process output on the screen. The longer term use of this information is for interactive diagnostics (by -verbal description of the visual attributes) and for open-loop on-line quality control systems.

A specific software module called the Print Fault Generator was developed to let the users validate the cause/effect relations and the visual representation produced by the CopyDesk. This module lets the user access the information either by the type of print fault (then choosing one of the causes) , or by the component of the process (then choosing one possible process problem and an associated print fault). Once the choices had been made, the software "printed" the result on the screen.

Corrective Actions : Costs and Times

The worksheets also helped define the way in which problems could be solved. This also defined the potential interaction with the press - the types of parameters that had to be modelled.

For each possible action, the time and materials cost was also specified. These vary with the type of printing press being used (a sophisticated press costs more to run) and with the types of materials (cardboard costs more than bible paper).

These sets of costs can be input to the model when running in problem-solving mode to estimate the productivity of the simulator user, and to show this user what the production costs are. When people understand the implications of their actions, they think before acting; in the printing industry this means running with less waste and producing at lower cost.

The underlying generic model can thus be used to simulate different production environments.

Conceptual Definition of Model

This task took the information from the generic process description and implemented it as a formal object-oriented model. This made sure that the topology was correctly described. At this time it became obvious that the superficial level of description in the generic machine description needed to be extended. In particular, specific objects had to be defined to deal with the relations between certain elements.

For example, in a printing press there is an element called a Blanket (the image transfer mechanism) and another element called a Plate (the image carrier). The way the. image is transferred from the Plate to the Blanket is a crucial part of the process. One of the important aspects is the Pressure between the Plate and the Blanket. This Plate-Blanket Pressure (PBP) is not a physical component of the press, how-ever it is a crucial element of the process and must be modelled separately.

It should be noted that the variation of the values of PBP depends on things like:

- The degree of wear of the Plate
  - This can depend on the amount of ink present on the plate and the length of time for which these ink values were substandard.
- The thickness of the undercoating (packing) of both the Plate and the Blanket.
- The thickness of the coating of paper dust that builds up on the Blanket during a press run
  - This can depend on the type of paper, the tack of the ink and the number of copies printed.

Each element (component or relation) has a set of values, each value is linked to the other elements whose variation may modify it.

The object-oriented approach lends itself well to this type of modeling. Objects are said to "communicate" with other objects with which they have functional dependencies. The way the values are recalculated (called "behaviour") in the Conceptual Definition, corresponds to the "methods" attached to an object.

There are currently about 150 "physical" objects modelled, about 20 relations, and over 200 behaviors.

Functional Definition of Simulator - Technical

This task took the information from the non-technical Functional Definition (what the simulator should do) and redefined it within the context of an Object-oriented methodology. This was done with computer-based CASE tools to provide coherence checking and reusability. A **sample page** from this definition is included in the annexes. The results of this task acted as input to the software development steps described below.

Software Development

The software development was done using CASE tools for modelling and C++ for programming. The basic philosophy was to implement formal high-level decorative structures and to automatically generate the low-level procedural code.

The initial development platform was MS Windows. This was chosen because of the low price of the hardware and the limited resources of the target users - the small and medium sized printing companies.

Overall Architecture

Formal Data Base

A formal data base, built with Paradox, holds the information about the process components, their relations, the overall topology, and the possible print faults.

Objects and Topology

These are basically as described in the Conceptual Definition above. A sample page from the data base is included in the annexes.

Behavior (methods)

The behavior of the objects is described in the data base, but is too complex to be automatically generated. The procedural routines are hand-coded and automatically linked later in the program production.

Code Generation

A set of routines was created which reads the data base and automatically generates most of the code for the simulator. The code generation is independent of the target machine.

Simulator

The simulator is the dynamic model of the conceptual definition. It initialises the various values, and propagates the information through the model according to the object topology and the associated sets of behavior.

For example, the thickness of the ink film on the Plate will be calculated by :

- Initializing the speed of the Duct Roller that picks up ink from a tank
- Calculating the rate of transfer of the ink to the various intermediate sets of rollers, and the evenness of the resulting ink film on the rollers
    - This depends on their physical state and their degree of distance and parallelism
- Calculating the degree of "travel" of the Oscillating Roller which moves back and forth to smooth out any local inconsistencies
    - This affects the evenness of the ink film.

The simulator accepts information from the user interface (actions on the press) and uses this to modify the values and recalculate the state of the process.

The simulator also recognises if there are process problems and if they are serious enough to show up on the output print copy. If they are, the information is sent to the CopyDesk module. Since there is a temporal element in the process model, the degree of intensity of a process problem can evolve over time. In this case, the information passed to the CopyDesk will evolve as well.

The simulator routines are completely portable. They are not linked to any operating system or C++ compiler. They have already been ported to Macintosh and have passed the first set of validations.

The portability is an important aspect for future process control applications.

Interface

The interface is the part that the user sees. It gives a graphical representation of the pressroom and the press. Each element of the press and the control mechanisms is represented and the user can "access" any element to verify its state.

This is a mouse-driven environment. The density of information is such that touch screens became impractical. Sample screens are included in the annexes.

Copy Generator

While many faults on a printed sheet can be calculated dynamically, in particular those relating to ink density or relative color juxtaposition ("fit"), others depend on the way the printed image was designed and require intense upstream analysis to see where the problems may arise.

An example of this is print images which use areas of solid tint (called "unscreened"). When certain types of process problems arise, the images in these areas may seem to "repeat" on the printed sheet. This is because the image is transferring onto an ink roller which has a smaller circumference than the plate and is re transferring onto the plate in an unwanted location.

The Copy Generator takes in the images to be printed and analyses the relative densities and placements. It then calculates the way certain print faults would look if they arose, and stores this information. If the image is being "printed" and if there is a process problem (as reported by the Simulator) that would make the print faults show up, the pre-calculated result is retrieved, its values adjusted for the intensity of the problem, and it is then "printed" on the computer monitor.

While it would be possible to calculate this sort of information "on the fly", the mount of data that would have to be held in memory would increase the hardware requirements to an unacceptable degree. It would also markedly increase the time needed for the display routine.

The performance goal has been that any print fault should be displayed within 10 seconds at the most . The benchmark machine is a 4S6/66 with 32Mo of RAM. The pre-calculation (of all possible print faults) done by the CopyGenerator currently takes 90 minutes on the same machine.

The CopyGenerator also handles more mundane tasks, such as calculating the relative densities for the print copy; information which is used to initialise the Simulator value when printing that image. This function corresponds to the real-world scanner values that are used to "preset" the ink profile on the printing press.

Copy Desk

One of the best ways to check if the model of the printing process is working correctly is to see if the output looks right.

The CopyDesk corresponds to the printer's "light table". It is the place where the printed copy can be laid out, checked against the customers proof copy, and examined for quality problems.

The function of the CopyDesk is to simulate the "print" function of the press, the effects that happen when the colors are laid on top of one another. Any information about process problems will also be integrated when "printing" the copy on the screen.

The CopyDesk maintains separate sets of information for each of the colors being printed and then combines them when printing the copy. In addition any physical faults with the paper surface (e.g. wrinkling due to excess humidity) are also stored in memory,

Image Display

The printed copy can be displayed as a fill sheet, or can have one quadrant blown up to occupy the full screen. ***Remember that the software is simulating a 70x102cm sheet on a 17" (43cm) monitor.***

The printed copy can be displayed side by side with the proof to visually check for differences and quality problems. This is what the printer does in the pressroom.

Diagnostic Tools

As one of the goals of the SHOTS project was to show printers how to recognise and diagnose process problems, it is necessary to simulate the diagnostic tools. These permit the printer to examine the dot structure of the image, to verify the relative densities for the colors, to determine the "trap" between overlapping colors and to check for gloss in the coated parts of the image.

NOTE This type of information is extremely important with regard to validating the simulator model. The dot structure is the "micro" representation of the process output; the print copy is just the "macro" representation.

The diagnostic tools include

- A ***8X*** or ***50X*** magnifier, which permits the user to see the simulated dot structure of the screened parts of the image.
- A manual densitometer for checking dot gain, density and trapping
- A gloss meter for checking gloss
- A scanning densitometer for evaluating the ink profiles

Testing the Simulator / Testing the User

The simulator is a functional model of the printing process. It is horrendously complex. Validating it is a daunting task. While some problems can be provoked by the process operator who can modify values from the control panel or mechanical settings on the machine. It is also necessary to validate machine failures or problems with the raw materials that are outside the operator's scope of action.

As part of the SHOTS project, a Problem Generator was constructed (the module called Trainer), which makes it possible to modify any of the parameters of the machine and to input that new state into the simulator to verify the behaviour of the model.

When the simulator is also used to train printers in trouble-shooting, this Trainer module is used to construct sets of problems for the trainee to solve. The problems can be combined into Scenarios, where different sets of problems will occur over time. After all, the production run is not finished just because the first set of problems has been solved.

<u>Problem Construction</u>

Defining a problem means

- Choosing a press configuration (2, 4 or 6 print units)
- Choosing the raw materials to be used (inks and papers)
- Deciding which images to print
- Defining the Problem Scenario
  - How many problems will occur at once
  - How many sets of simultaneous problems will occur in sequence

<u>Cost Specification</u>

A set of costs can be associated with the predefine problem. See above for more details.

<u>Trace Files for Evaluation</u>

The system can produce different types and levels of trace files.

The lowest level is the internal reporting of the simulator. This is used to validate the model and the simulator functions.

This level shows each initial value, each propagated value, each modification of the values, the presence and intensity of any print problems, input information from the interface, etc.

The most often used level is the User Trace file. This shows

- Any existing problems (if serious enough to show upon the print output)
- All user actions
- The results of the actions on the set of problems (it gets better or worse)
- The cost and time of each action
- The overall production and cost figures.

When used in a structured training program, the instructor will use the Traces to help the trainee improve their skills, to learn how to look at a problem and why one type of solution is preferable.

Results

The goals of the project have been attained. The simulator was delivered to the project participants two years after the project started. It is currently being extended to become a commercial product, and the first sales are expected to start in late 19%.

The underlying model has attracted wide attention from other sectors of the industry, in particular the packaging sector. Other projects are interested in reusing this model, particularly in the gravure and flexographic domains.

The types of results are described below.

Formal Model of Offset Printing

The formal model is expressed in the various databases and in the behavior of the defined objects. This work is an indispensable starting point for all future modelling of the printing industry.

Print Fault Generator

This was a preliminary result from the project, but is useful as a "stand-alone". It lets printers check the library of print faults (as "printed on the screen") to see which one corresponds best to their current problem. This module will underlie future stand-alone diagnostic modules.

Training and Diagnostic Simulator

This permits the user to validate the fidelity of the underlying model. It has immediate applications for the printing industry in the training and trouble-shooting aspects.

Cost Modelling

This gives an overall model of the costs involved in running a print job. It extends the current production costing models to give specific information for all of the operator actions. It permits the generic model underlying the simulator to be adapted for different press configurations and for different print jobs.

Thematic Network

A user network has been setup to continue co-operation on these subjects. This is composed of the initial project members and extends to other countries. Versions of the project results were installed before the formal end of the project in Canada, Australia and the USA. The users in these countries are currently validating the simulator to make sure that the underlying model is, in fact, generic.

Commercial Product

The results will be launched as a commercial product in June 1996, and sales are expected to start before the end of that year. Members of the initial project will continue to receive new versions of the simulator as they appear.

Process Control Applications

The suppliers in the project are co-operating with Sinapse to explore how the underlying model can be used to improve the pressroom technology.

Conclusions

The project has been successful in reference to its immediate, two-year, goals. It has produced results with a usable simulator. The long term success of the project will be measure by the sales of the simulator and by the ways in which the underlying model ise used to improve the technology of the press and pressroom and the habits of those who work there.

Acknowledgements

This project was funded by the European CRAFT program, as contract BRE CT93.0895. The partners in the project are listed in the annexes on the page headed ABOUT SHOTS (this is taken from the user interface).

References

The primary references are to be found in the SHOTS technical report submitted to the European Community. This is not a public document.

For more information about this project, readers are invited to contact theauthor of this report.