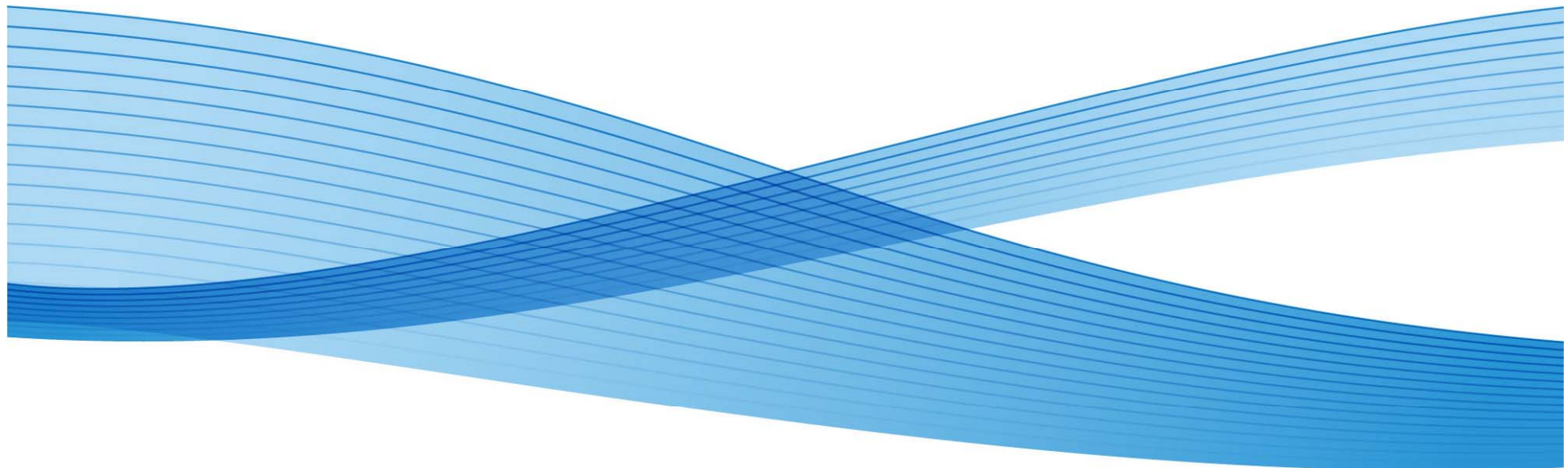


■ *The 9th International Conference on
Software Methodologies, Tools and Techniques*
(SoMeT 2010 in Yokohama)

Development and Evaluation of HAYST Method Tool.
(Combination Software Testing by orthogonal array)

October 1, 2010 (Thu)

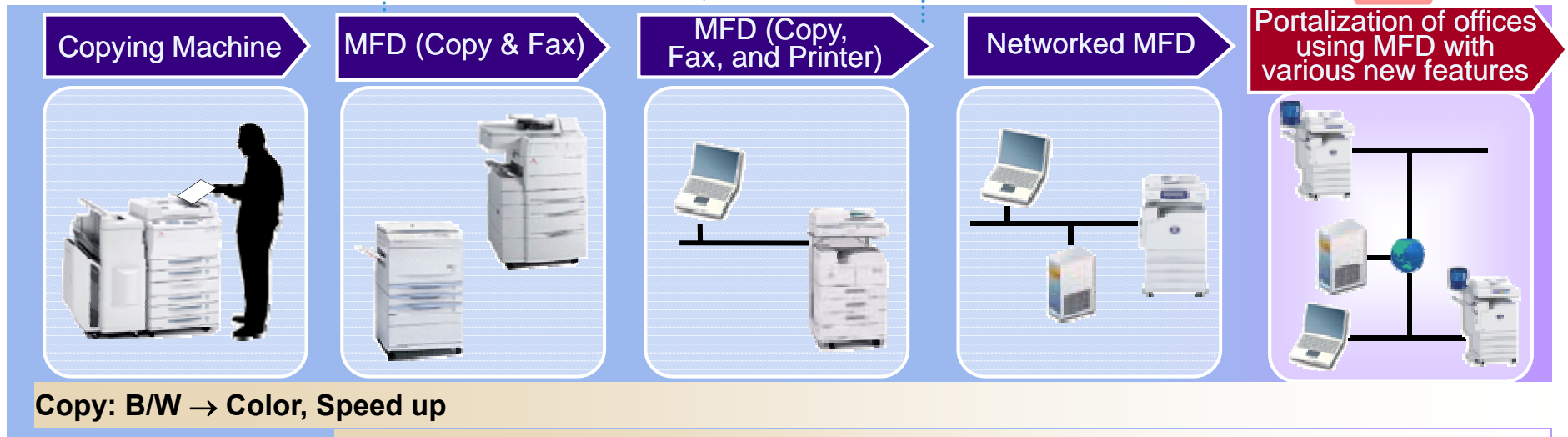
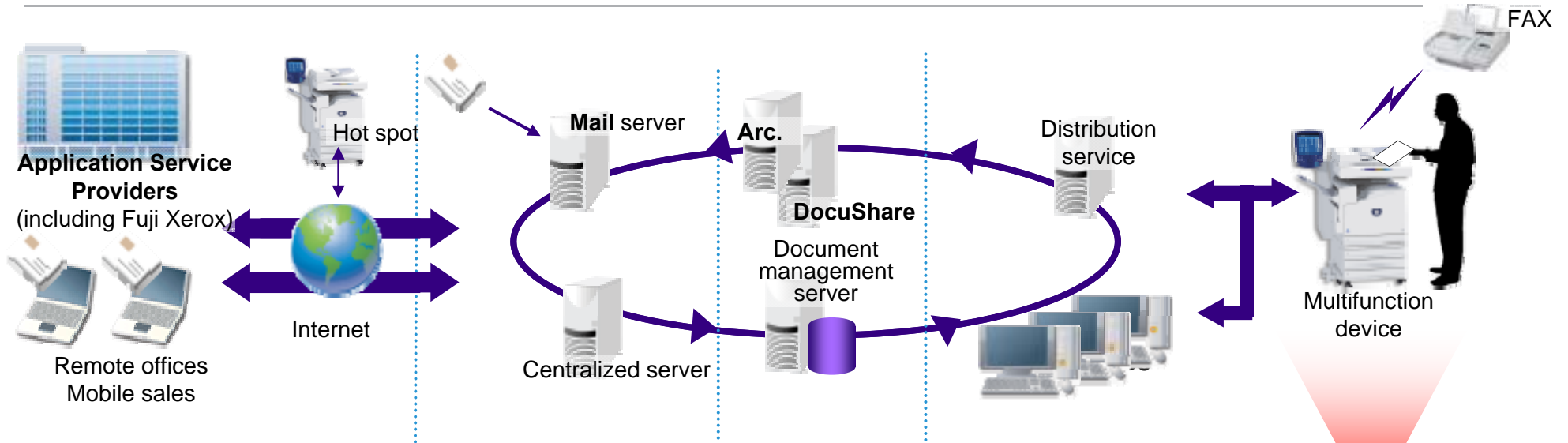


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Quality Assurance Group, Fuji Xerox Co., Ltd. / Faculty of Engineering Kagawa University.

Abstract

1. Introduction
2. Outline of HAYST method
3. Design policy of HAYST method tool
4. Functional outline of HAYST method tool
5. Characteristic algorithm of HAYST method tool
6. Effect of HAYST method tool
7. Conclusion

1. Introduction



Copy: B/W → Color, Speed up

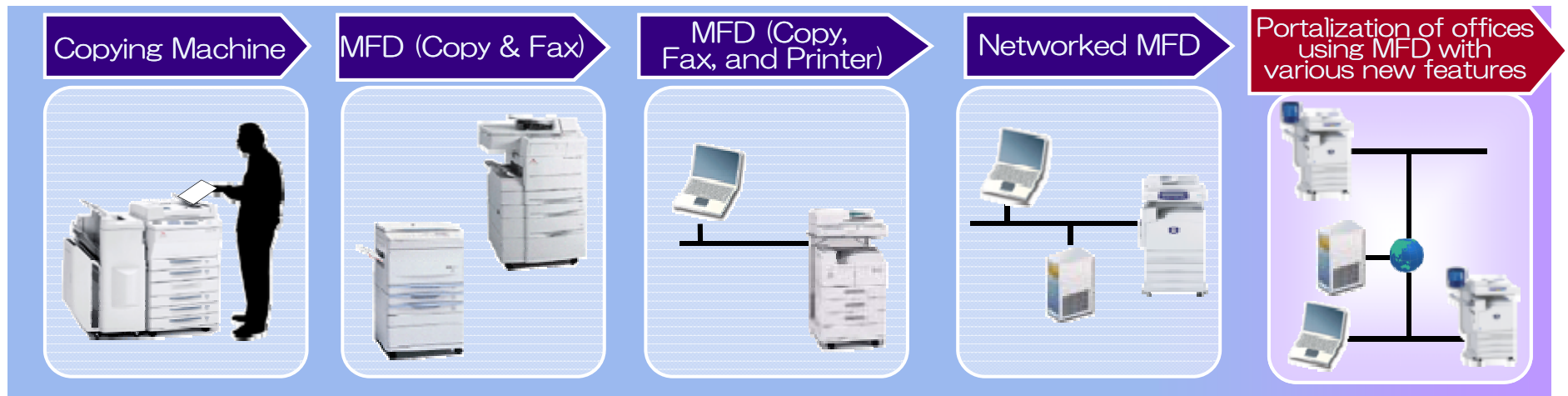
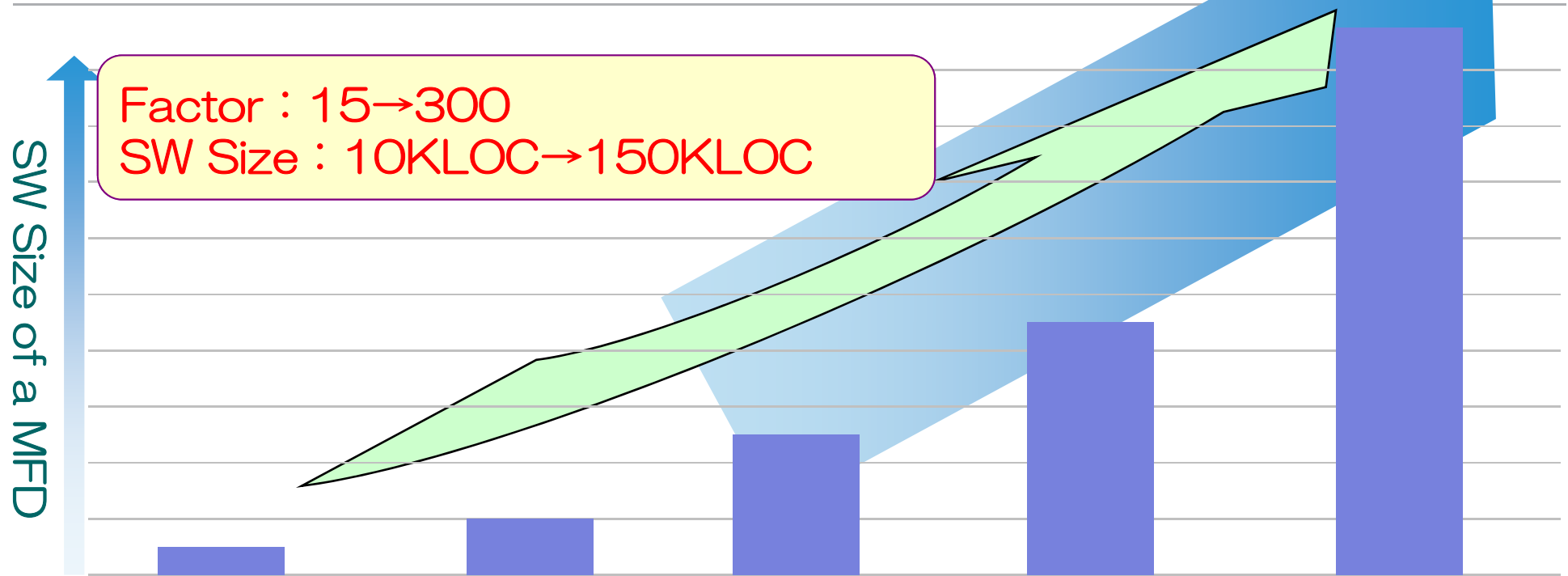
Copy/Fax → Integrated

Information distribution from MFDs

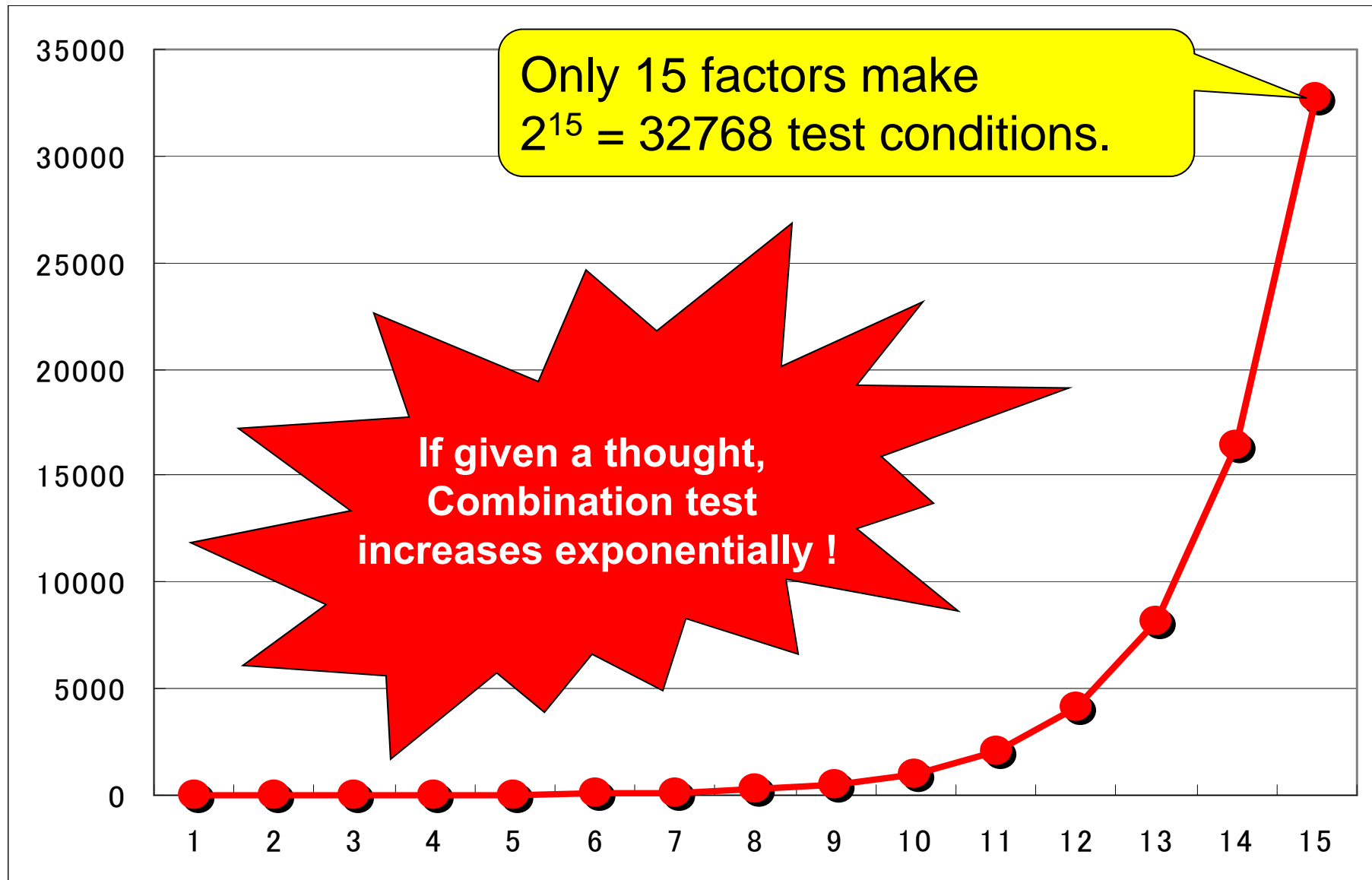
Document management using MFDs

Meeting various business needs using MFDs

Increase of SW size about a MFD in Fuji Xerox



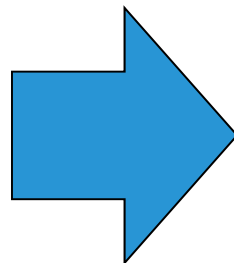
Combination test increases exponentially



Aim of HAYST method and Tool

- Quality improvement using combination testing.
- Efficiency of test for time to market.
 - At first, creation of test matrix by orthogonal array using HAYST method was done using Excel. It took average 2 weeks that is, man-hours of 10 man-days (= 50 man-hours) for creation of test matrix.

70 factors
20 constraints



L_{128} Orthogonal array

Orthogonal array

Factor

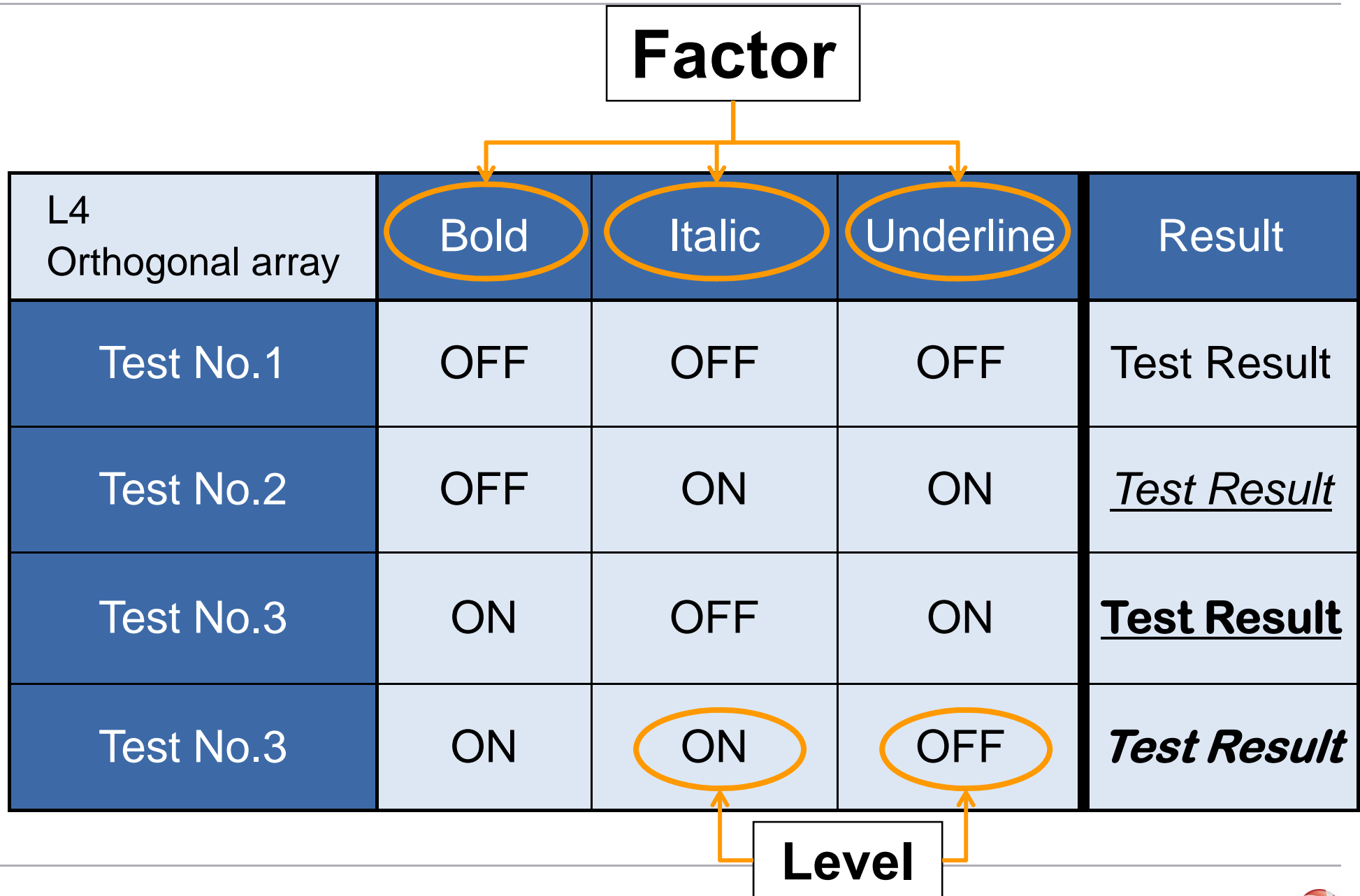
Character modification factors and levels

Factor	Level
Bold	OFF
	ON
Italic	OFF
	ON
Underline	OFF
	ON

L4 orthogonal array	A	B	C
1	0	0	0
2	0	1	1
3	1	0	1
4	1	1	0

Level

Allocation result

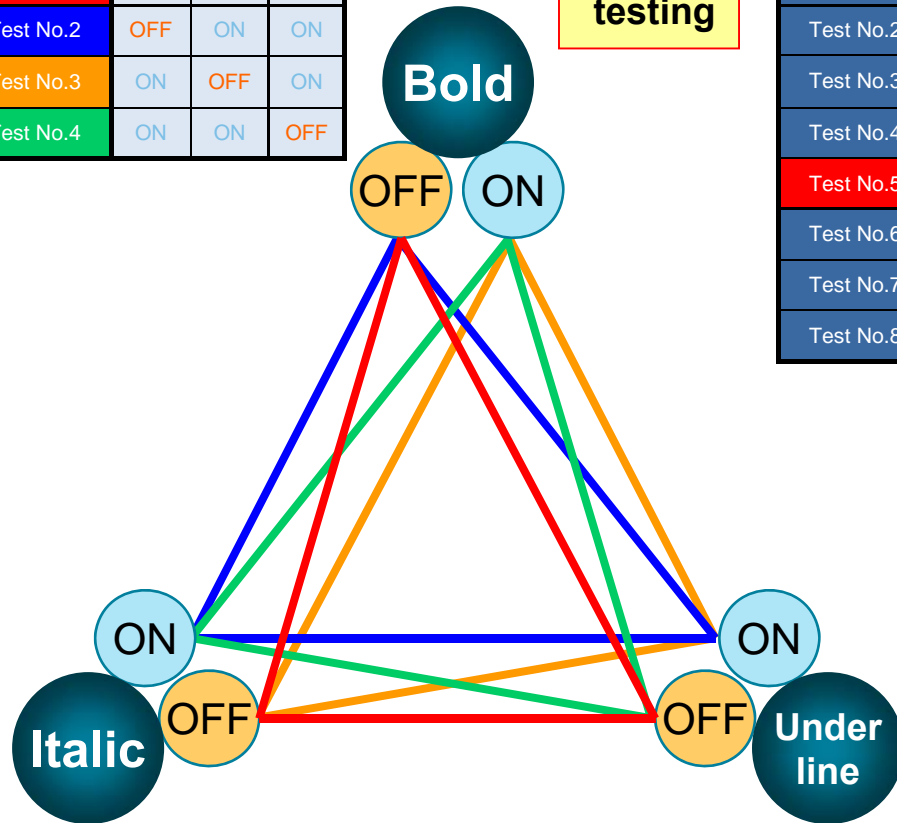
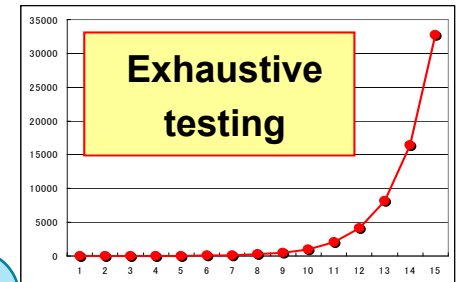


Combinations that the orthogonal array covers.

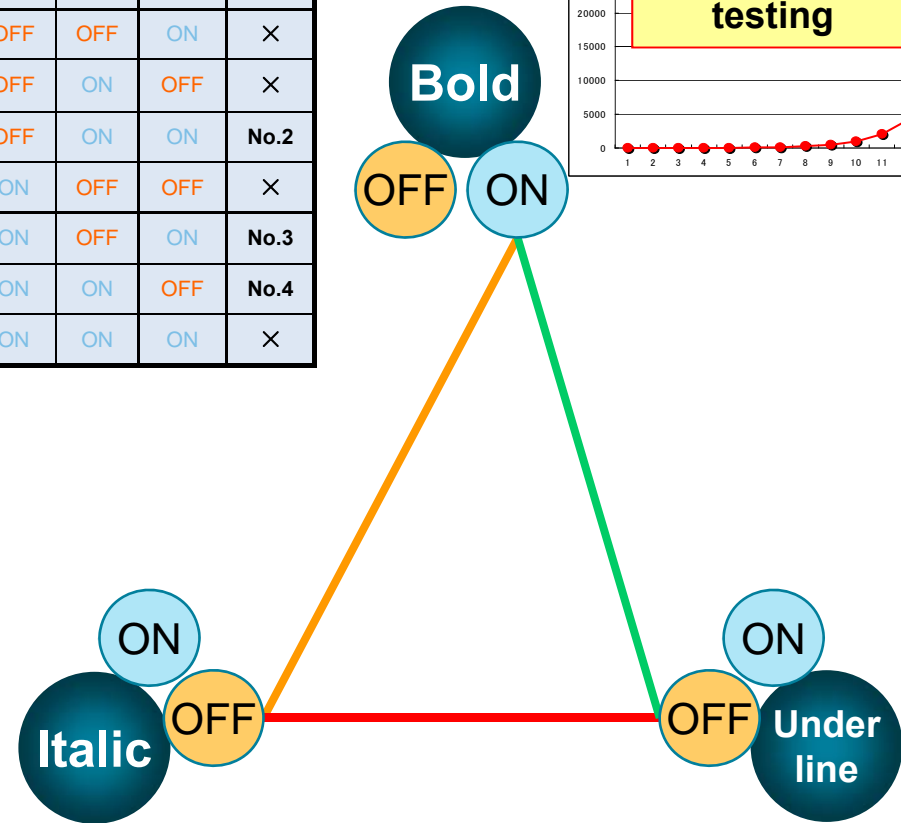
L4 orthogonal array	Bold	Italic	Under line
Test No.1	OFF	OFF	OFF
Test No.2	OFF	ON	ON
Test No.3	ON	OFF	ON
Test No.4	ON	ON	OFF

OA testing

All combinations	Bold	Italic	Under line	L4
Test No.1	OFF	OFF	OFF	No.1
Test No.2	OFF	OFF	ON	×
Test No.3	OFF	ON	OFF	×
Test No.4	OFF	ON	ON	No.2
Test No.5	ON	OFF	OFF	×
Test No.6	ON	OFF	ON	No.3
Test No.7	ON	ON	OFF	No.4
Test No.8	ON	ON	ON	×



All the combinations between 2 functions exists.
(This state can be defined as combination cover rate 100%)



In all the combinations, the combination that does not exists in the orthogonal array also appears (However, Test frequency expands in an exponential manner) If seen properly, No. 2, 3, 5 which does not appear in the orthogonal array are unit test content

Coverage of L_8 orthogonal array

L_8 Orthogonal array

	A	B	C	D	E	F	G
	1	2	3	4	5	6	7
1	1	1	1	1	1	1	1
2	1	1	1	2	2	2	2
3	1	2	2	1	1	2	2
4	1	2	2	2	2	1	1
5	2	1	2	1	2	1	2
6	2	1	2	2	1	2	1
7	2	2	1	1	2	2	1
8	2	2	1	2	1	1	2

Using L_8 orthogonal array, you get 8 combination test.

(1) Pair combinations: 100%(84)

$${}_7C_2 \times 4 = 84$$

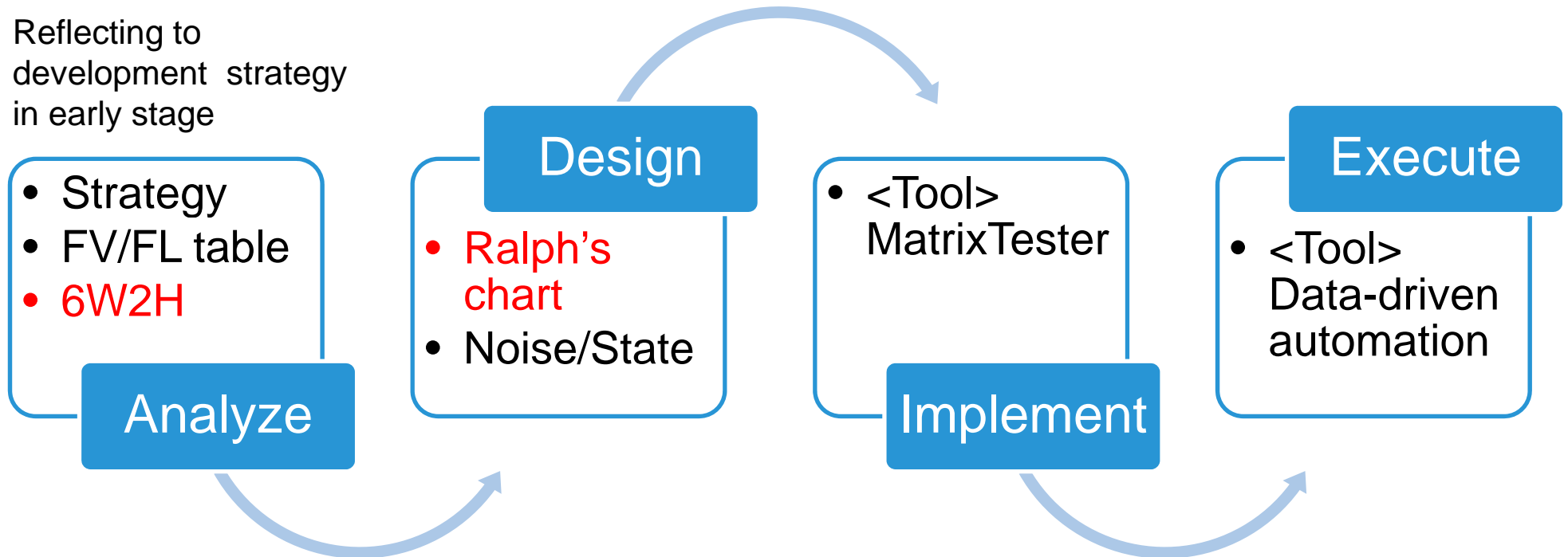
(2) Triple combinations: 90%(252)

$${}_7C_3 \times 8 = 280$$

		A		B		C		D		E		F		G	
		-1	-2	-1	-2	-1	-2	-1	-2	-1	-2	-1	-2	-1	-2
A	-1			0/2	0/2	0/2	0/2	0/2	0/2	0/2	0/2	0/2	0/2	0/2	0/2
	-2			0/2	0/2	0/2	0/2	0/2	0/2	0/2	0/2	0/2	0/2	0/2	0/2
B	-1	0/2	0/2			0/2	0/2	0/2	0/2	0/2	0/2	0/2	0/2	0/2	0/2
	-2	0/2	0/2			0/2	0/2	0/2	0/2	0/2	0/2	0/2	0/2	0/2	0/2
C	-1	0/2	0/2	0/2	0/2			0/2	0/2	0/2	0/2	0/2	0/2	0/2	0/2
	-2	0/2	0/2	0/2	0/2			0/2	0/2	0/2	0/2	0/2	0/2	0/2	0/2
D	-1	0/2	0/2	0/2	0/2	0/2	0/2			0/2	0/2	0/2	0/2	0/2	0/2
	-2	0/2	0/2	0/2	0/2	0/2	0/2			0/2	0/2	0/2	0/2	0/2	0/2
E	-1	0/2	0/2	0/2	0/2	0/2	0/2	0/2	0/2			0/2	0/2	0/2	0/2
	-2	0/2	0/2	0/2	0/2	0/2	0/2	0/2	0/2			0/2	0/2	0/2	0/2
F	-1	0/2	0/2	0/2	0/2	0/2	0/2	0/2	0/2	0/2	0/2			0/2	0/2
	-2	0/2	0/2	0/2	0/2	0/2	0/2	0/2	0/2	0/2	0/2			0/2	0/2
G	-1	0/2	0/2	0/2	0/2	0/2	0/2	0/2	0/2	0/2	0/2	0/2	0/2		
	-2	0/2	0/2	0/2	0/2	0/2	0/2	0/2	0/2	0/2	0/2	0/2	0/2		

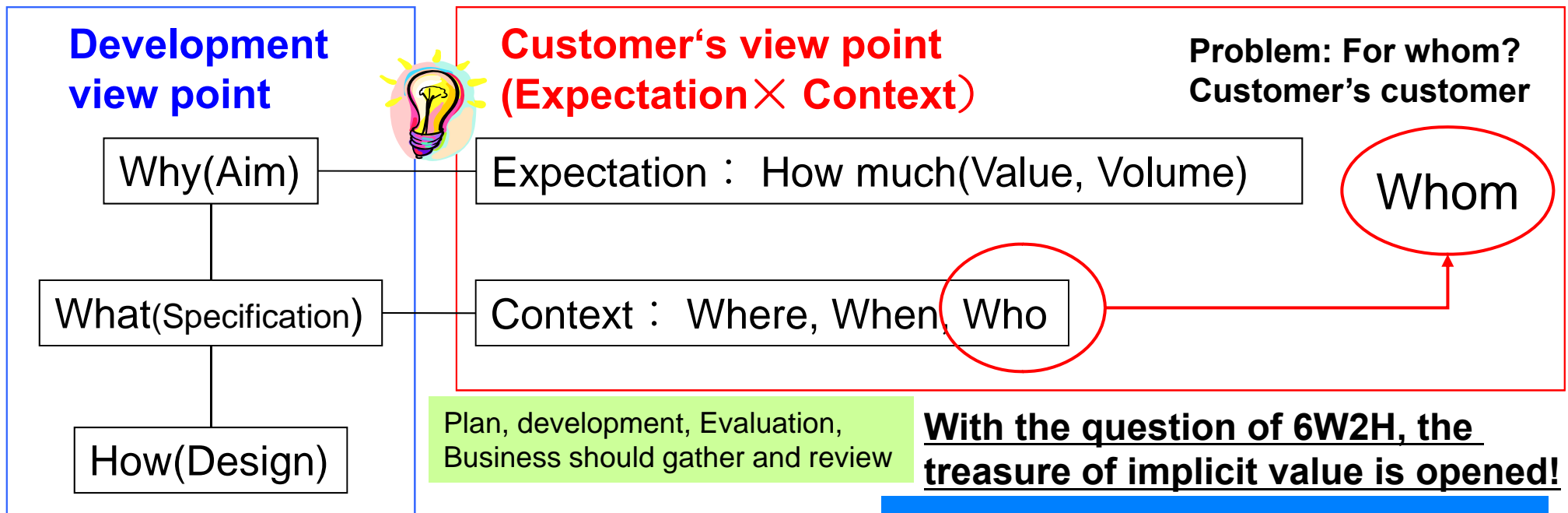
2. Outline of HAYST method

Reflecting to development strategy in early stage



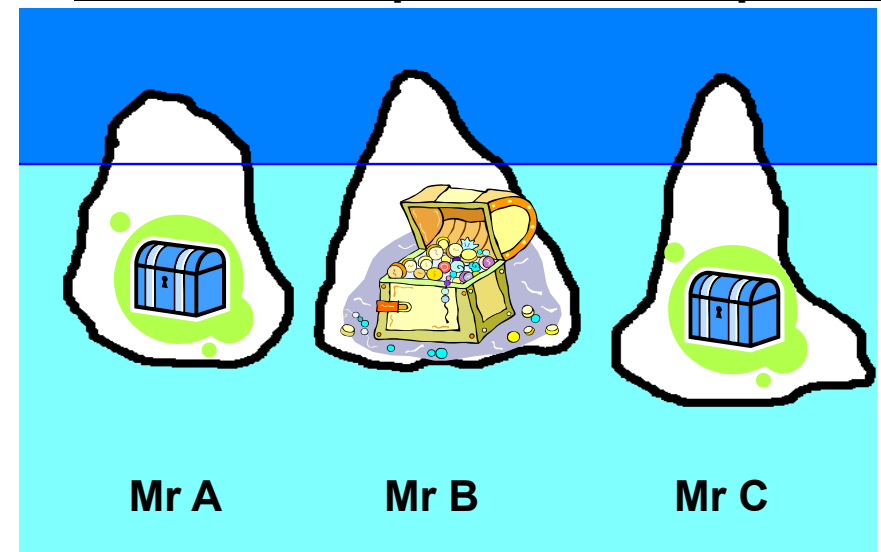
- The purpose of 6W2H is to find rough factors
- The purpose of Ralph's chart is to find factors and levels

View point to select factor and extraction method (6W2H)

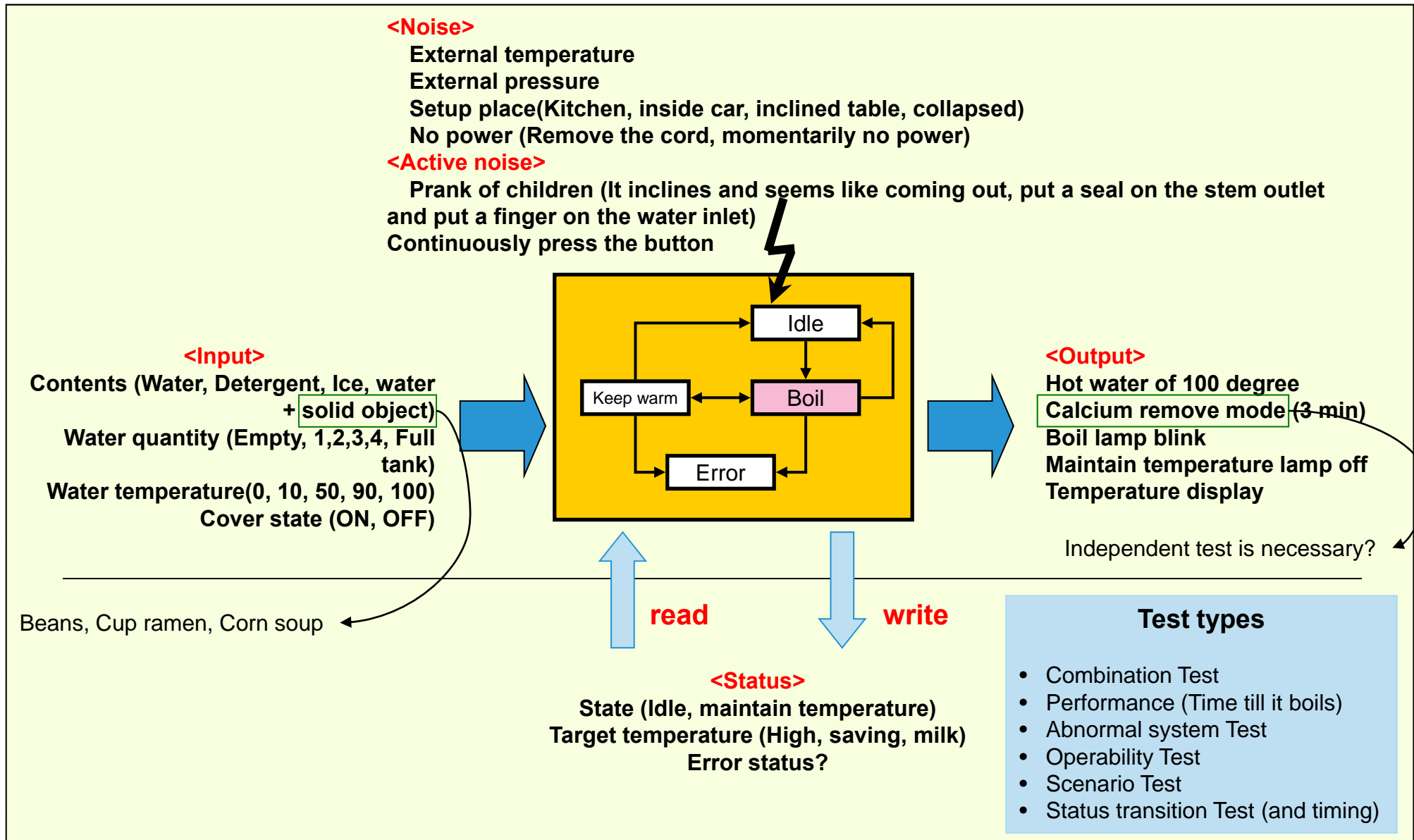


Eg) You can find other factors with 'Why?'

1. Think of the factor of the function called 'Underline'
2. Purpose = The character should be remarkable
3. Search for other factor with same purpose
4. Search for 'Expand', 'coloring', 'enclose in circle', etc.
5. The found factor should be more with a combination with 'underline' !



Example of Ralph's chart: Electronic pot (factors/levels)



3. Design policy of HAYST method tool

◆ Instinctive usability

- Using instinctively without seeing the manual
 - ◆ Icons used in GUI are instinctive
 - ◆ Technical terms of Design of Experiments are not used
 - ◆ “Operation guide” to navigate the operations was prepared

◆ Integration of latest assignment technique

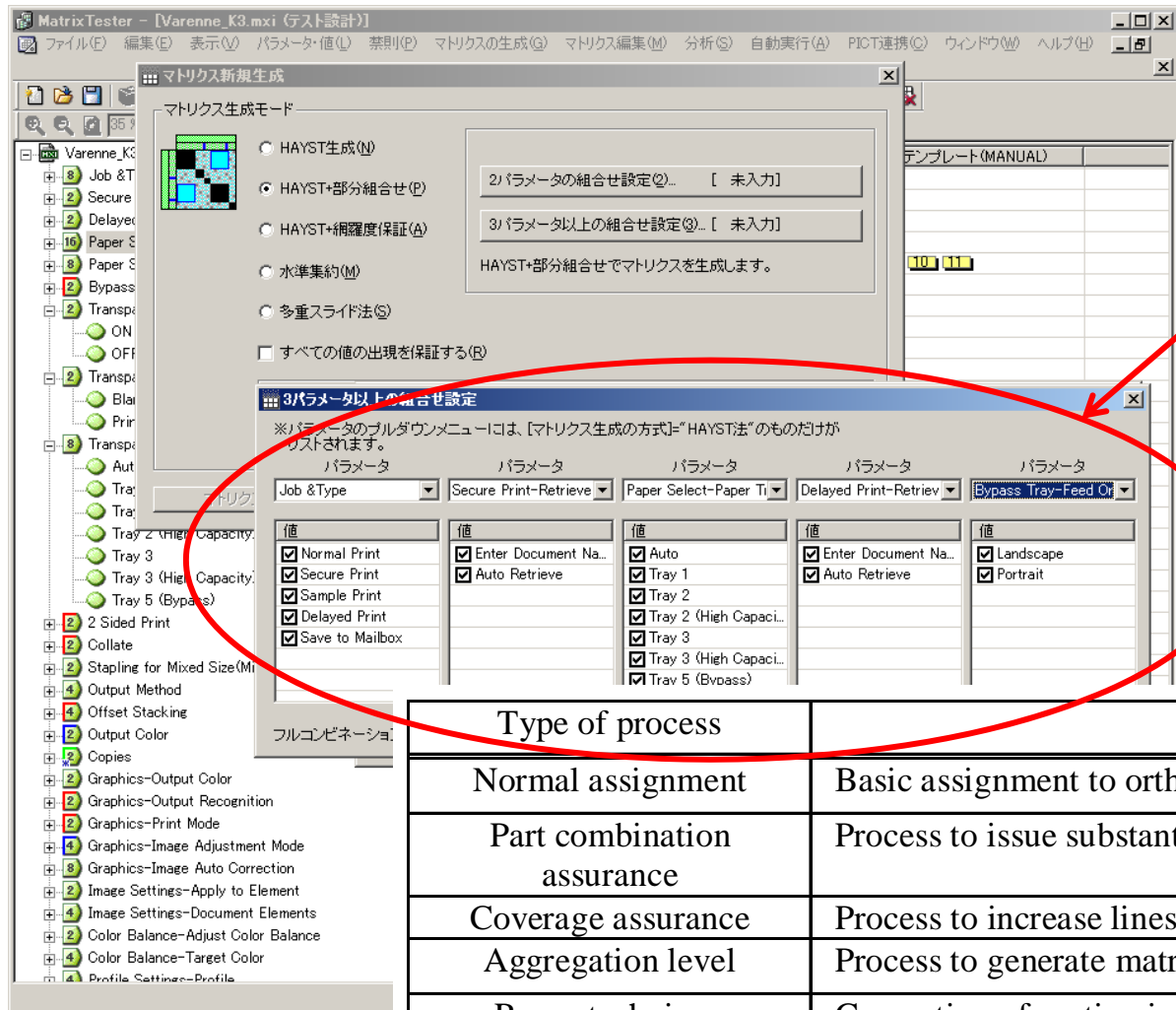
- Function and attribute were neatly separated
 - ◆ Especially attribute was largely used

4. Functional outline of HAYST method tool ◆ Input ◆

The screenshot shows the MatrixTester software interface. On the left is a tree view of parameters for 'Varenne_K3.mxi'. The main window displays a table titled '16ブロックテンプレート(MANUAL)' with columns for '値名' (Value Name) and '16ブロックテンプレート(MANUAL)'. The table lists various paper sizes and their weightings. A green box labeled 'Constraint' points to the '16ブロックテンプレート(MANUAL)' column. A green box labeled 'Weighting' points to the numerical values in the '16ブロックテンプレート(MANUAL)' column.

Input type	Explanation
Factor (Parameter)	Name of parameter to be combined
Level (Value)	List of values existing in parameter
Importance of factor	Factors are grouped and it is possible to specify strength for group
Importance of level	Importance of level (Weighting)
Constraint information	Constraint condition in combination between levels
Assignment method	Normal assignment, Partial combination assurance, rating assurance, Level consolidation, Room technique, Strength 3, PICT calling
Detection bug information	Type of bug
Specific factor	Value generation type, Fixed value, Sequence number
Form style	Form style at the time of Excel output
Auto execution support information	Windows Dialog GUI information for auto execution

4. Functional outline of HAYST method tool ◆ Process ◆



Part combination assurance

Type of process	Explanation
Normal assignment	Basic assignment to orthogonal array
Part combination assurance	Process to issue substantial combinations partially for important factors
Coverage assurance	Process to increase lines of matrix till it reaches specified coverage
Aggregation level	Process to generate matrix by orthogonal array of specified size
Room technique	Generation of nesting in orthogonal array
Orthogonal arrays of strength 3	Assignment where all level combinations between any 3 factors are appeared.
PICT call	Conversion into form where tool (PICT) of Pairwise can be read

4. Functional outline of HAYST method tool ◆ Output ◆

No.	自動実行	テスト結...	メモ	Job &Type	Secure Print-Retrieve Document Name	Delayed Print-Retrieve Document Name	Paper Select-Paper Size
1	-	-		Normal Print	Enter Document Name	Enter Document Name	A1 (594 x 841mm)
2	-	-		Secure Print	Enter Document Name	Enter Document Name	A2 (420 x 594mm)
3	-	-		Sample Print	Enter Document Name	Auto Retrieve	A3 (297 x 420mm)
4	-	-		Delayed Print	Enter Document Name	Auto Retrieve	A1 (594 x 841mm)
5	-	-		Save to Mail...	Auto Retrieve	Enter Document Name	A2 (420 x 594mm)
6	-	-		Normal Print	Auto Retrieve	Enter Document Name	A3 (297 x 420mm)
7	-	-		Secure Print	Auto Retrieve	Auto Retrieve	A1 (594 x 841mm)
8	-	-		Sample Print	Auto Retrieve	Auto Retrieve	A2 (420 x 594mm)
9	-	-		Normal Print	Auto Retrieve	Enter Document Name	A4 (210 x 297mm)
10	-	-		Secure Print	Auto Retrieve	Enter Document Name	Statement (5.5 x 8.5")
11	-	-		Sample Print	Auto Retrieve	Auto Retrieve	Ledger (11 x 17")
12	-	-		Delayed Print	Auto Retrieve	Auto Retrieve	A4 (210 x 297mm)
13	-	-		Save to Mail...	Enter Document Name	Enter Document Name	Statement (5.5 x 8.5")
14	-	-		Normal Print	Enter Document Name	Enter Document Name	Ledger (11 x 17")
15	-	-		Secure Print	Enter Document Name	Auto Retrieve	A4 (210 x 297mm)
16	-	-		Sample Print	Enter Document Name	Auto Retrieve	Statement (5.5 x 8.5")
17	-	-		Normal Print	Auto Retrieve	Enter Document Name	A5 (148 x 210mm)
18	-	-		Secure Print	Auto Retrieve	Enter Document Name	A6 (105 x 148mm)
19	-	-		Sample Print	Auto Retrieve	Auto Retrieve	B5 (182 x 257mm)
20	-	-		Delayed Print	Auto Retrieve	Auto Retrieve	Postcard (4 x 6")
21	-	-		Save to Mail...	Enter Document Name	Enter Document Name	Photo 2L (5 x 7")
22	-	-		Normal Print	Enter Document Name	Enter Document Name	A5 (148 x 210mm)
23	-	-		Secure Print	Enter Document Name	Auto Retrieve	A6 (105 x 148mm)
24	-	-		Sa			
25	-	-		No			
26	-	-		Se			
27	-	-		Sa			
28	-	-		De			
29	-	-		Sa			
30	-	-		No			
31	-	-		Se			
32	-	-		Sa			
33	-	-		No			
34	-	-		Se			
35	-	-		Sa			
36	-	-		De			
37	-	-		Sa			

Test Matrix

Type of output	Explanation
Test matrix	Result of assignment to orthogonal array
Test script	Orthogonal array is output to Excel in script format in each line
Appearance status	Appearance frequency and combination that does not appear
Rating	Rating of combination between 2 factors and 3 factors
Round Robin table	Round Robin table indicating appearance status of level combination between 2 factors and 3 factors
Constraint graph	Graph indicating hierarchical status of constraint and that data table
Test analysis result	Result of analysis of existence position of bug based on the test result

4. Functional outline of HAYST method tool ◆ Output ◆

◆ Rating

網羅率計算[HAYST法]

網羅率計算モード

全パラメータ間の網羅率を計算(A)

指定パラメータ間の網羅率を計算(B)

3パラメータ間の網羅率計算

計算する(I)

概算モード(R)

チェックすると計算時間を短くするが、この時、組合せ網羅率は正しい値にならない。
概算モードでの制限事項は次の通り。

- ・禁則を考慮しない
- ・融合した単位での網羅率を計算

Item	2 parameters	3 parameters
Combination rating	87.0%	61.5%
Number of all the combinations excluding constraint	9614	407054
Number of combinations covered by matrix	8364	250515
Number of combinations not covered by matrix	1250	156539
Total of constraint combination	31	4167
Number of parameters considered in combination	39	39
Number of values considered in combination	143	143
Matrix size estimate from degree of freedom	105	105
Template size	L128	L128
Number of test items	128	128

計算開始(N)

	2パラメータ間	3パラメータ間
組合せ網羅率	87.00%	61.54%
融合した単位での網羅率	99.53%	82.47%
禁則考慮の有無	有	有
禁則処理を除いた全ての組合せ数	9614	407054
マトリクスが網羅する組合せ数	8364	250515
マトリクスが網羅しない組合せ数	1250	156539
禁則組合せの全ての数	31	4167
組合せに考慮したパラメータの数	39	39
組合せに考慮した値の数	143	143
生成モード	HAYST生成	HAYST生成
自由度からのマトリクスサイズ見積り	105	105
テンプレートサイズ	L128	L128
テスト項目数	128	128

クリップボードへコピー(O)

閉じる(C)

ヘルプ(H)

4. Functional outline of HAYST method tool ◆ Output ◆

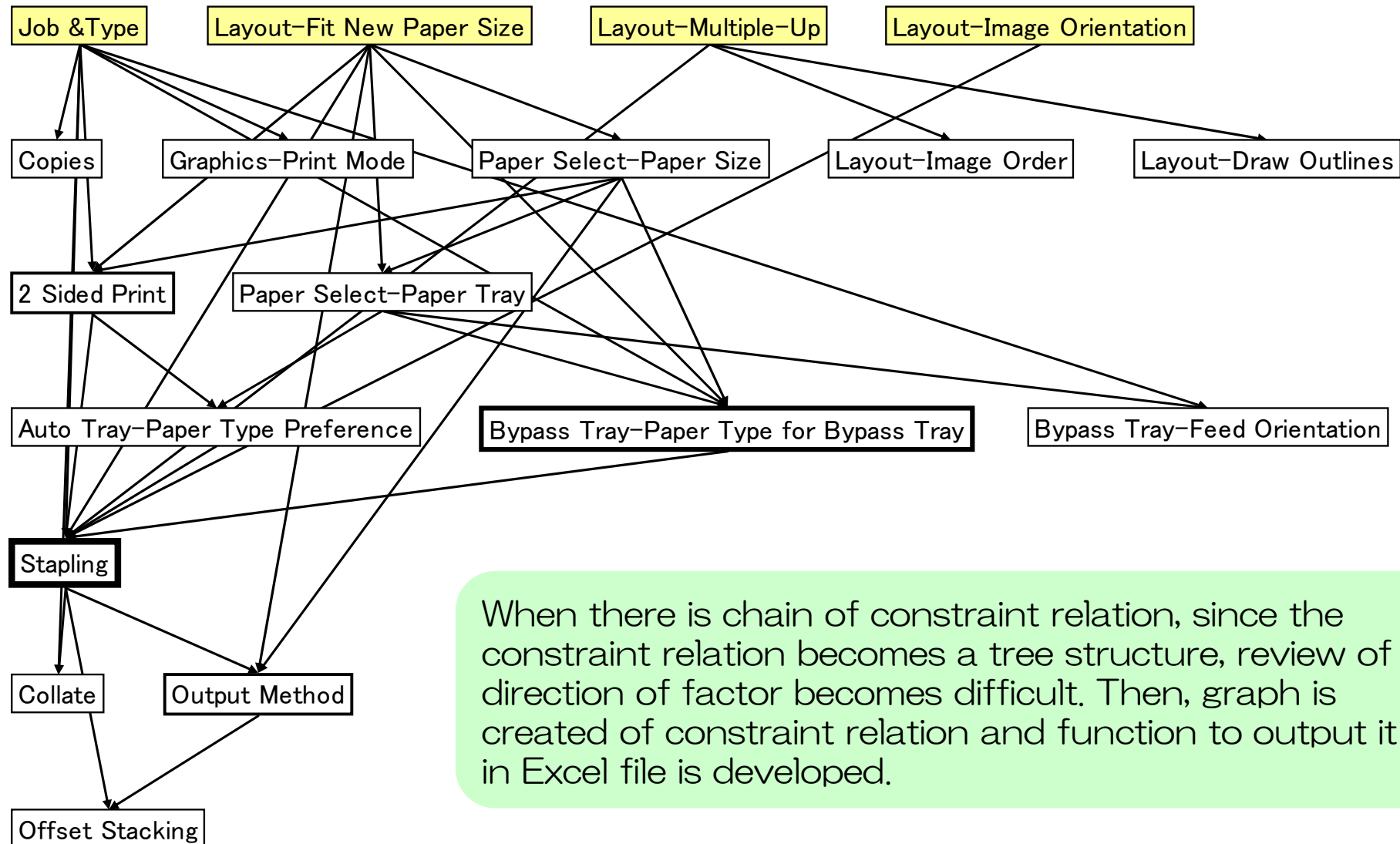
◆ Round robin table



In the tool, color coding of cells is done, and device to easily detect the existence location of combination bug (Yellow, Red) and test leakage (Grey) was innovated.

4. Functional outline of HAYST method tool

◆ Constraint graph



5. Characteristic algorithm of HAYST method tool

◆ Part combination assurance

■ Difference between Pairwise and HAYST

- ◆ In Pairwise tool of PICT etc., total strength (How many combinations of factors will be assured?) can be specified, but part combination assurance is not supported.
- ◆ In HAYST method tool, after executing assignment to normal orthogonal array, method of adding insufficient combinations from the view point of strength for specified factor group was adopted. This is because a large amount of combination between 3 factors is already seen in orthogonal array.

◆ Conversion to PICT format

- MatrixTester can call PICT tool.

6. Effect of HAYST method tool ◆ Functional comparison ◆

Item	PICT	HAYST method tool
Importance of factor	None	Present
Importance of level	None	Present
Constraint information	Handling of NULL is manual	Auto
Assignment method	3 types of normal generation, strength specification, additional generation	7 types of normal assignment, part combination assurance, rating assurance, level consolidation, Room technique, strength 3 and call PICT
Particular factor	None	Value generation format, fixed value, sequence number
Form output	Table format to EXCEL	Table format to EXCEL, free form to EXCEL (each test case)
Auto execution support	None	Windows Dialog GUI support
Appearance status	Not required (All appearances are assumed)	Present
Rating calculation	None	Rating between 2 factors, Rating between 3 factors
Round Robin table	None	Present
Constraint graph	None	Present
Test result analysis	None	Present

6. Effect of HAYST method tool ◆ Generate test case ◆

Size of factor to be combined	PICT	HAYST method tool	
	Strength 2	Normal generation	
Without constraint	3^4	13 (47.2%)	16 (55.6%)
	3^{13}	20 (60.1%)	64 (92.1%)
	$4^{15}3^{17}2^{29}$	36 (80.1%)	256 (98.7%)
	$4^13^{39}2^{35}$	29 (84.0%)	256 (99.0%)
	2^{100}	16 (91.4%)	128 (99.6%)
	10^{20}	216 (20.4%)	345 (24.3%)
	4^78^6	89 (37.5%)	64 (31.9%)
	$2^{12}4^{10}8^{10}16^1$	163 (60.7%)	128 (58.5%)
	$2^{11}4^{21}8^{13}16^6$	338 (59.5%)	256 (55.7%)

In small test
PICT is
better

In big test,
HAYST is
better

With constraint

No.	Factor size	Number of constraints of factor unit	Number of constraints of level unit	Number of PICT Test cases	Number of HAYST method test cases
1	$2^{25}3^44^35^26^17^113^1$	33	272	180 (68.2%)	159 (65.9%)
2	$2^23^34^15^16^111^1$	8	91	79 (63.4%)	106 (74.0%)
3	$2^{11}3^24^3$	8	17	29 (71.6%)	41 (81.2%)
4	$2^53^54^45^46^7$	6	25	65 (58.4%)	82 (70.0%)
5	$2^{17}3^{14}4^35^16^{27}8^1$ $9^114^117^120^22^{11}$	15	356	Process aborted	1600 (34.3%)

For assignment of multi level, multi factors with constraint used in normal test, HAYST method tool equivalent to PICT tool of Pairwise.

5. Conclusion

- ◆ Conventionally, HAYST method tool was developed
- ◆ Various assignment techniques are installed in HAYST method tool
- ◆ Any one can use it easily, and man-hour could be reduced from 60 hours to 2 hours as compared to the case without tool
- ◆ For assignment of multi level, multi factors with constraint used in normal test, HAYST method tool equivalent to PICT tool of Pairwise
- ◆ In future, I will make a more effective tool

Thank you for your kind attention



Test life cycle process in HAYST method.

