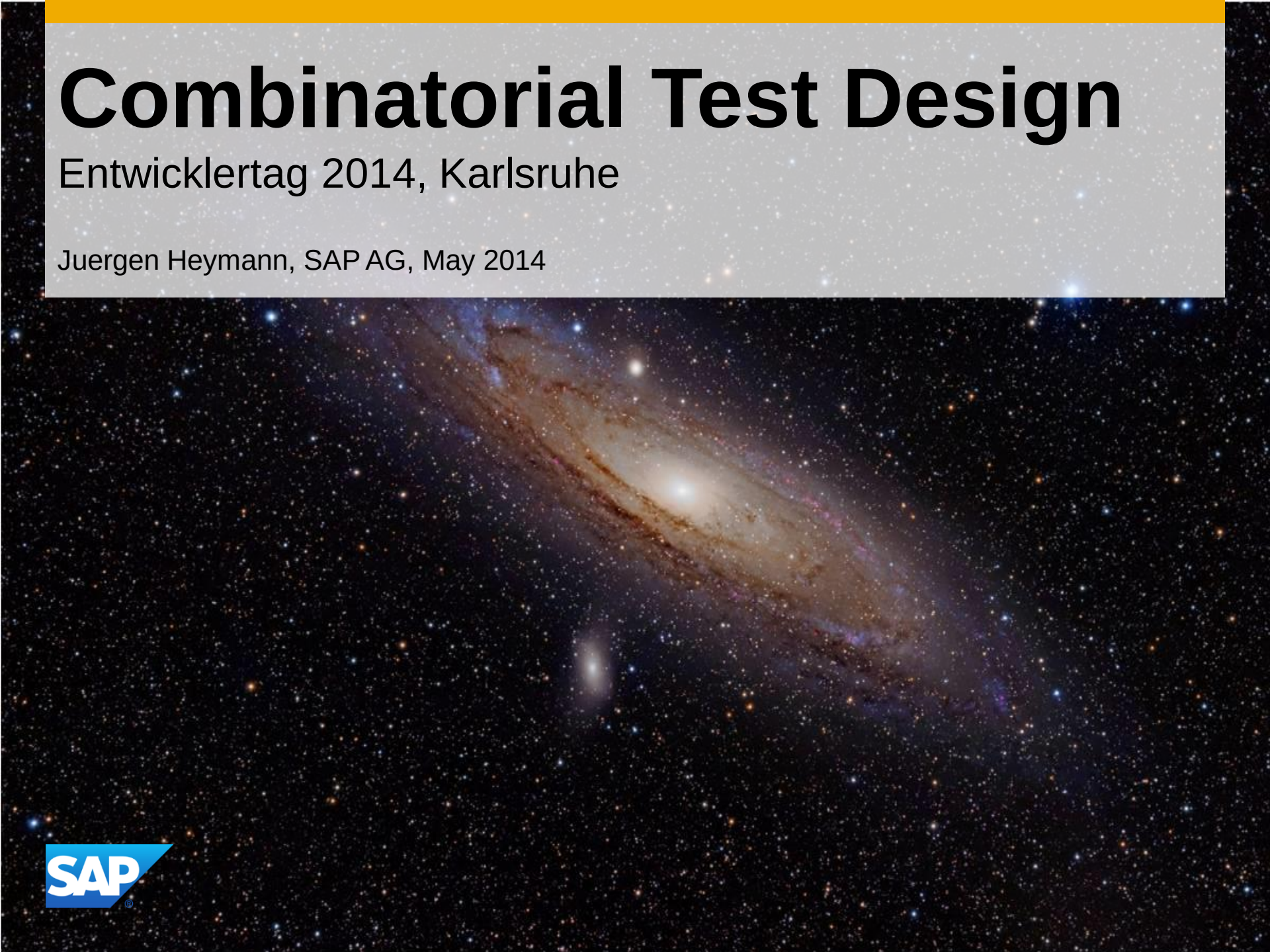
Combinatorial Test Design

Entwicklertag 2014, Karlsruhe

Juergen Heymann, SAP AG, May 2014



The Problem of Testing

- SAP produces very complex and highly configurable software
  - using direct input, configuration settings, transactional data
- We cannot test all combinations!
- . . . but customers do use 'all combinations'

There are more theoretically possible execution paths in a typical program of 10000 lines of code than atoms in the universe.
Assuming 250 independent branches: $2^{250} \approx 10^{77}$

What is "Combinatorial Test Design"?

- **A 'black box' test technique**

  (= views function of software from the outside)

  - **that combines several test design techniques**

    - **to deal well with the problem of 'all combinations'**

Outline

A. **Introduction to the Method**

B. **Examples from Application Modeling & Testing**

C. **Is it worth it?**

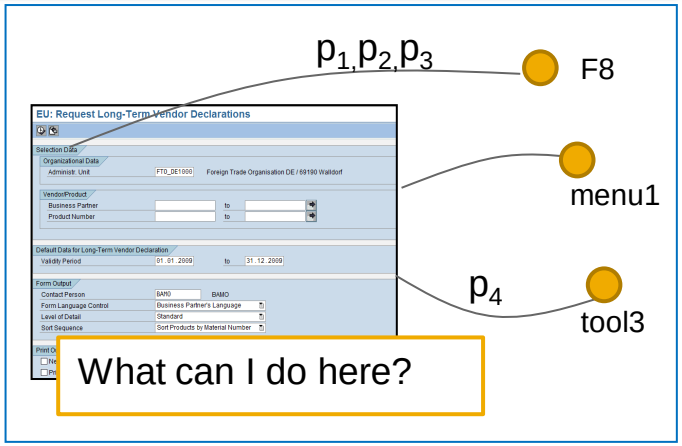
Introduction to the Method

Step 1: Finding the Use Cases / Test Cases

Assume you have a certain scope of functionality to test…

Step 1. **Find 'use cases' / test cases (UI example)**

- Ask "What can I do here?" ('user action')
- Each action triggers a behavior / function
  - 'Enter' / action-buttons but also menu items, tool bar clicks, …
  - API: call of a service / function / method / …
- Each action / 'use case' becomes a test case



This should give you a complete list of possible actions / test cases that cover the test object – and have to be tested (test = setup-action-verify)

Step 2: Find the parameters of the test / action

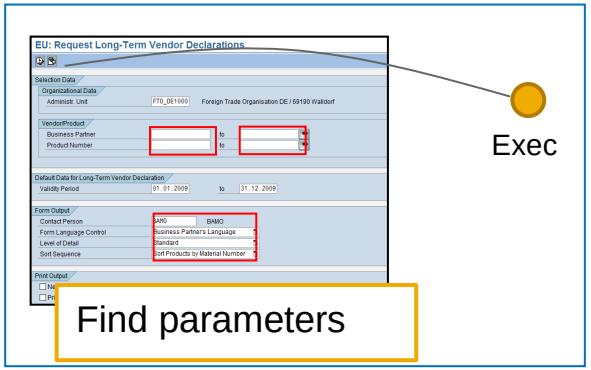
Step 2. **Find parameters of the test case**

Differentiate between

- **Dummy Data**: just needed to run tests, not varied in testing, e.g. customer address, article name
- **Test Model Relevant Parameters**: affect the behavior of code under test (CUT)

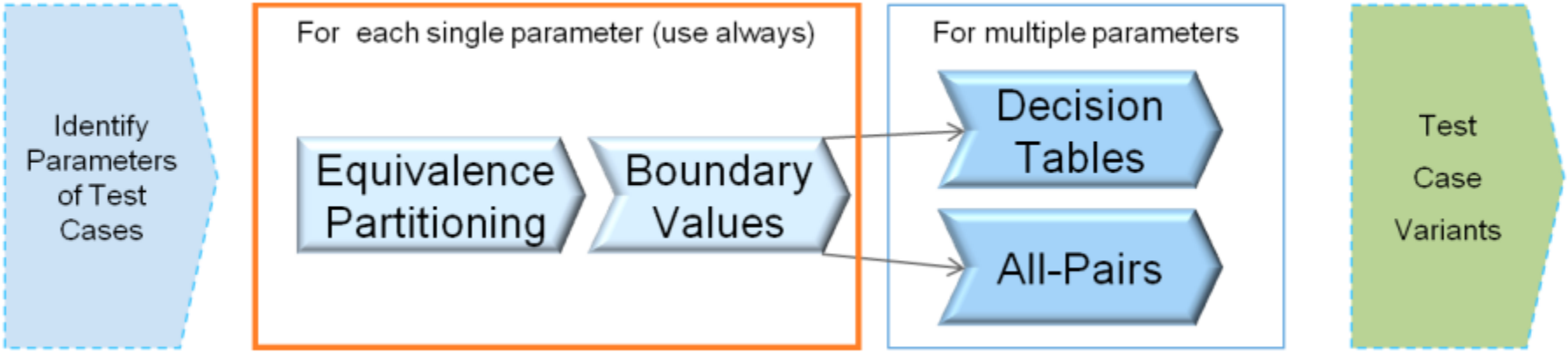
Test Relevant Parameters can be found in

- **Direct Input** e.g. parameters in API, on screen
- **Application Configuration**
- **Object Data** in DB



This gives you the set of parameters that are relevant for this test case

Parameter Oriented Test Design



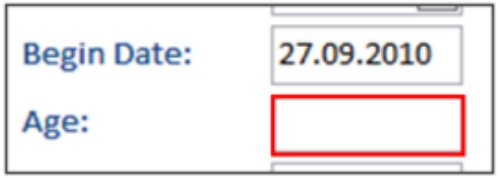
These 4 test design methods helps us to cover the parameter space in a smart way to find **more defects** with **less effort**!

The methods focus on **functional correctness**.

1: Identify Equivalence Classes

Example: Insurance Handling

- 'Age' field is age of applicant
- Contracts / formulas are different for *age groups*: **18...30, 31...50, 51...65**
- Outside the above age groups, no insurance policies are offered



Equivalence Class Representives

Classes "<18", "18-30", "31-50", "51-65", ">65"

Values for Test

illegal: 16, 66

valid: 20, 40, 55

2: Analyze Boundary Values

… to be considered in edge cases

Programming errors often happen at the boundaries of

- value domains
  e.g. at edges of allowed value ranges (equivalence classes)
- implementation logic
  e.g. first/last item in table, zero runs of a loop, . . .

Boundary Values (from Insurance Application)

Classes "<18", "18-30", "31-50", "51-65", ">65"

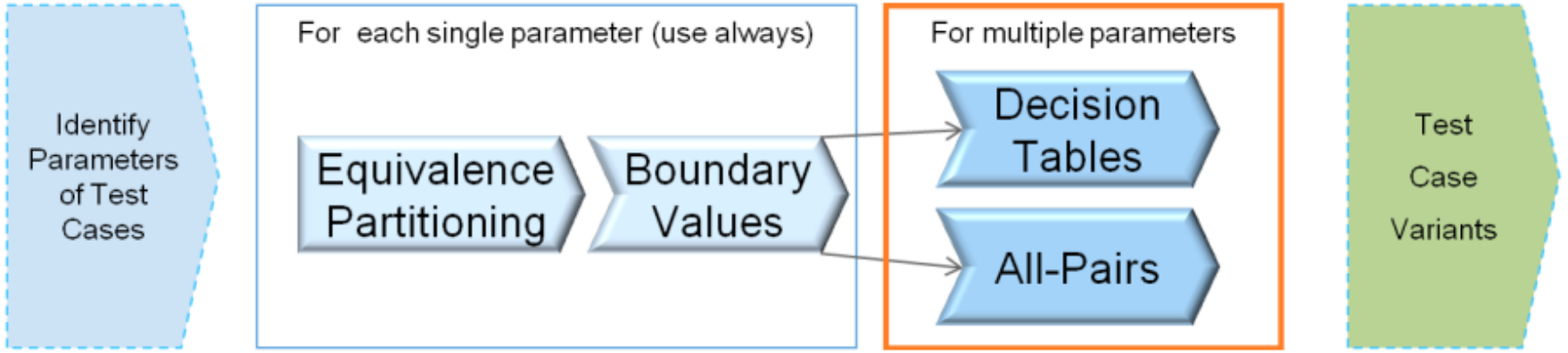
Values for Test

illegal: -1, 17, 66

valid: 18, 30, 31, 50, 51, 65

⇒ Test with both boundaries, not just a middle representative! ⇐

Handling Multiple Parameters



We have applied 'Equivalence Classing' and 'Boundary Value Analysis' to individual parameters.

Now: How define **combinations of parameters** for functional testing?

3: Decision Tables – for small models

Example: Account Opening

Approach (again): Find the *parameters* and the values

Specification: Successful opening of an account requires that the applicant identifies himself through an **identity card**. Minors also require **consent of their parents**. When an account is opened, an overdraft limit can be granted. The preconditions for this are that the **credit check** is successful and that the applicant is **legally an adult**.

But many tests have more than 4 parameters …

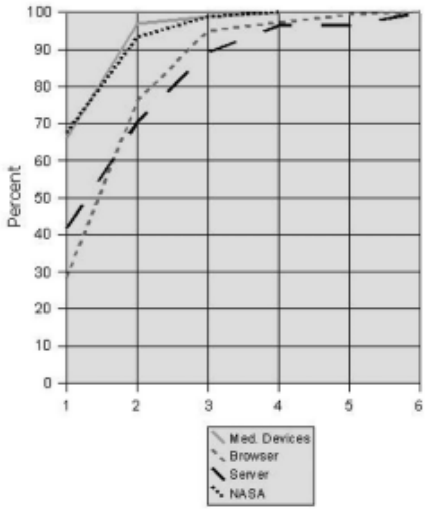
Let’s focus on a method that supports this case very well …

4: All-Pairs Testing – The Foundation

The Empirical Foundation: Most faults (70-90%) occur by combining two parameters 'just right'

All-Pairs Testing

- Generates minimal test case variants that cover all pair combinations
- Is a proven industry best practice



All-Pairs Testing – the Key Concept

What it means to 'combine all pairs':

All values

P1	P2	P3
0	0	0
1	1	1

Not effective

All combinations

P1	P2	P3
0	0	0
0	0	1
0	1	0
0	1	1
1	0	0
1	0	1
1	1	0
1	1	1

Not efficient

All value pairs

P1	P2	P3
0	0	0
0	1	1
1	0	1
1	1	0

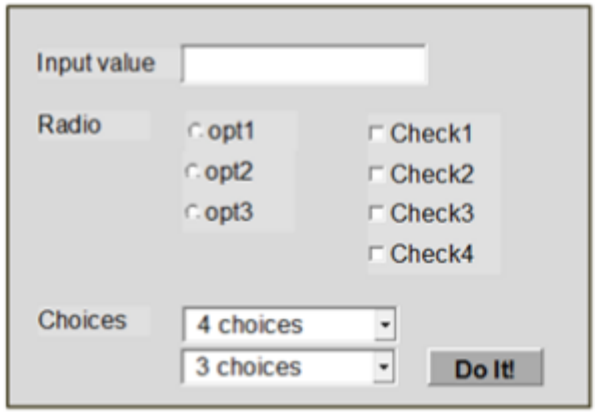
Efficient and effective

The 'savings' increase exponentially with the number of parameters

- E.g. 500 binary parameters can be covered with All-Pairs with 20 test cases

An All-Pairs Example

Some parameters of a function ...



Exhaustive test:

3 x 2x2x2x2 x 4 x 3 = 576 !

Model defines variables and values (PICT)

```
# Demo model for All-Pairs Training
#

Radio: 1,2,3
Check1: 0,1
Check2: 0,1
Check3: 0,1
Check4: 0,1

Choices1: 1,2,3,4
Choices2: 1,2,3
```

All-Pairs Generation Tool (PICT)

	Radio	Check1	Check2	Check3	Check4	Choices1	Choices2
1	1	0	0	0	0		
2	3	1	1	1	1		1
3	2	1	0	1	0		
4	2	0	1	0	1	1	1
5	3	1	0	0	1	1	2
6	2	0	1	1	0	4	2
7	1	0	1	0	1	4	3
8	1	1	0	1	0	3	1
9	1	1	0				
10	3	0	1				
11	3	1	1				
12	2	1	0	0	1	3	3
13	2	0	0	1	0	2	1
14	3	1	0	1	0	4	3

All-Pairs: 14 test cases!

All-Pairs Tool Support

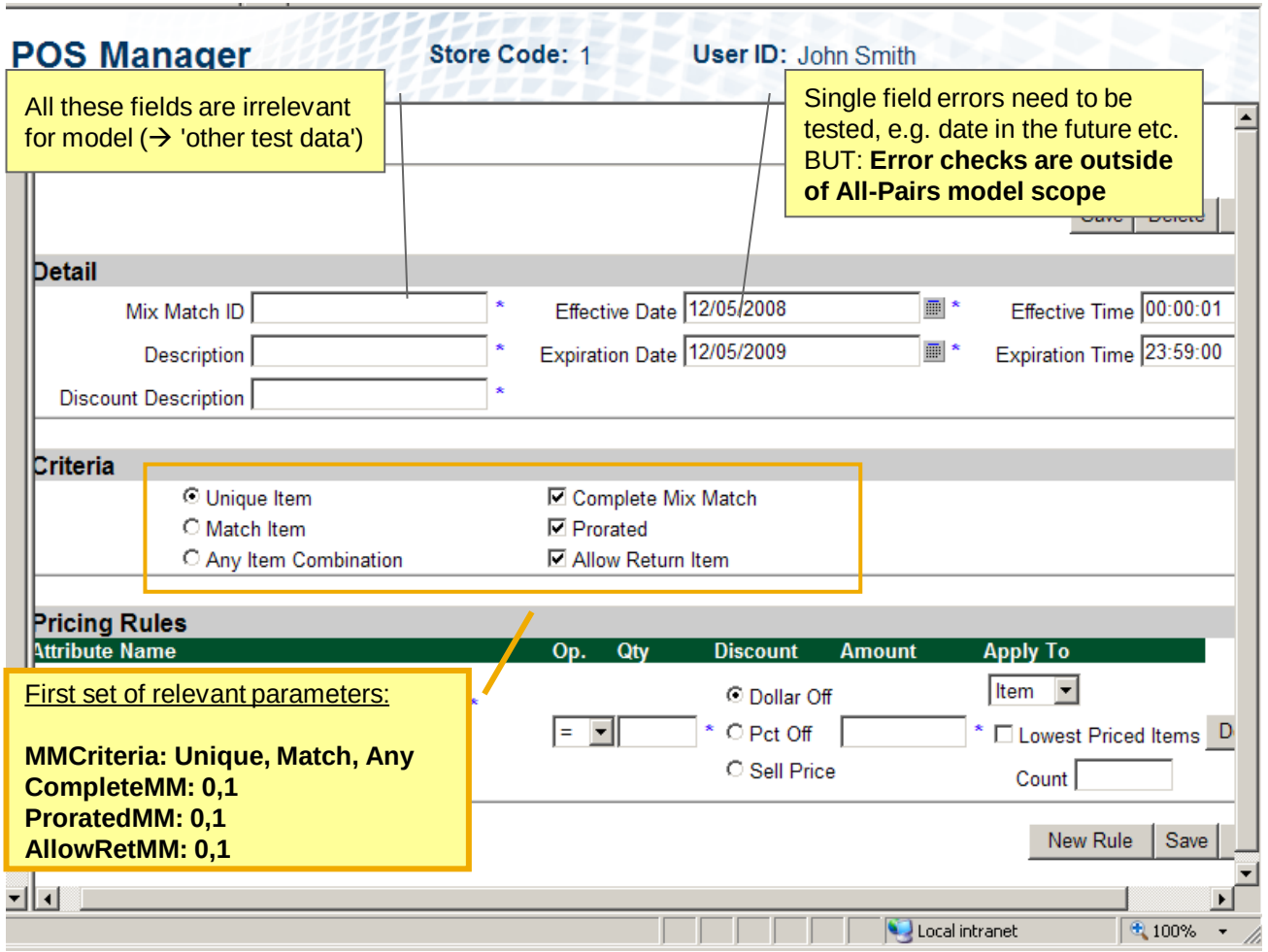
You cannot generate 'minimal pair coverage' by hand!

- We use the PICT engine from Microsoft + XLS as wrapper for convenience

Examples

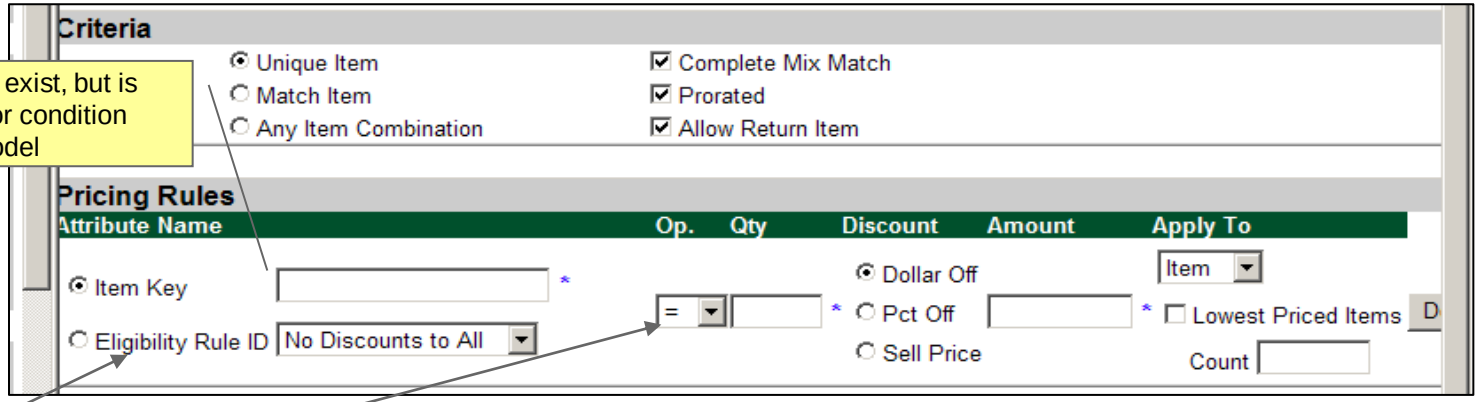
Example 1: Retail Pricing

Retail Management System – Sales Pricing



Combining all techniques 2

ItemKey: must exist, but is single-field error condition
➔ ignore in model



EligibilityRule1: ItemKeyExisting, NoDiscountsToAll, AllItems, Cosmetics, VenderSelection, UnitChargeDiscount
Operation1: Greater|GreaterEQ, EQ, LessEQ|Less
aliasing : we consider Greater|GreaterEQ 'almost the same' / equivalent; they are iterated but generate no addtl. pair coverage

Qty : 2
Qty: states how many items of the same type (item key) need to be bought before the special price / … applies.
Qty=2 covers the case that the program identifies at least 2 separate items to belong to the 'special' (as 'condition items').
You need the proper test data to 'trigger' this quantity

Discount1: DollarOff, PctOff, SellPrice

Amount: ignored for model, just use any test data; error checks: amount off > price, pct off > 100, Sell price > orig price

ApplyTo1: Item, Group

constraint: LowestPriceItem only used with EligibilityRules; item/group only with item
LowestPriceItems1: 0,1

count semantics?
Count1: 0, 1, 10

Example 2: FINDSTR (Windows Cmd tool)

```
Searches for strings in files.

FINDSTR [/B] [/E] [/L] [/R] [/S] [/I] [/X] [/V] [/N] [/M] [/O] [/P] [/F:file]
        [/C:string] [/G:file] [/D:dir list] [/A:color attributes] [/OFF[LINE]]
        strings [[drive:][path]filename[ ...]]

  /B          Matches pattern if at the beginning of a line.
  /E          Matches pattern if at the end of a line.
  /L          Uses search strings literally.
  /R          Uses search strings as regular expressions.
  /S          Searches for matching files in the current directory and all
              subdirectories.
  /I          Specifies that the search is not to be case-sensitive.
  /X          Prints lines that match exactly.
  /V          Prints only lines that do not contain a match.
  /N          Prints the line number before each line that matches.
  /M          Prints only the filename if a file contains a match.
  /O          Prints character offset before each matching line.
  /P          Skip files with non-printable characters.
  /OFF[LINE]  Do not skip files with offline attribute set.
  /A:attr     Specifies color attribute with two hex digits. See "color /?"
  /F:file     Reads file list from the specified file(/ stands for console).
  /C:string   Uses specified string as a literal search string.
  /G:file     Gets search strings from the specified file(/ stands for console).
  /D:dir      Search a semicolon delimited list of directories
  strings     Text to be searched for.
  [drive:][path]filename
              Specifies a file or files to search.
```

Model File (PICT Syntax):

```
# PICT model for FINDSTR
#
# Consider all switches indepe
#------------------------------


# which files
F: /F, _
S: /S, _
P: /P, _
OFF: /OFF, _
D: /D:1;2, _


# type of match
B: /B, _
E: /E, _
X: /X, _
regex: /L, /R, _
V: /V, _

# print format
N: /N, _
M: /M, _
O: /O, _
```

9	Testcase variants (copy from pict output)												
	1	2	3	4	5	6	7	8	9	10	11	12	1
	F	S	P	OFF	D	B	E	X	regex	V	N	M	O
1	_	_	/P	/OFF	/D:1;2	/B	/E	_	_	/V	/N	_	/O
2	/F	/S	/P	_	_	_	_	/X	/L	_	_	/M	_
3	/F	_	_	/OFF	_	/B	/E	/X	/L	_	/N	_	_
4	_	/S	_	_	/D:1;2	_	_	_	/L	/V	_	/M	/O
5	_	/S	_	_	_	/B	/E	_	_	_	_	/M	_
6	/F	_	/P	_	/D:1;2	_	_	/X	/R	_	/N	_	/O
7	/F	/S	_	/OFF	_	_	/E	_	/R	/V	/N	/M	/O
8	_	_	/P	/OFF	/D:1;2	/B	_	/X	/R	/V	_	/M	_
9	/F	/S	_	/OFF	/D:1;2	_	_	/X	_	_	_	_	/O
10													

Example 3: Code Level (C++)

Generated test cases → generated test code

```
enum t_dataType         { _int, _string };
enum t_dataDist         { _empty, _single_val, _single_val_full, _sequential, _random,
enum t_scanScenario     { _no_values, _one_value, _two_values, _all_values, _non_exist
enum t_operator         { _equal, _non_equal, _match, _similarity_search, _all };
//...

typedef struct t_caseRow {
    t_dataType          dataType;
    t_dataDist          dataDist;
    t_scanScenario      scanScenario;
    t_operator          op;
//...
};

//--------------------------- AllPairs generated combination cases  ------------------
t_caseRow testCases[] = {
    { _int, _uniform, _two_values, _equal, _first_row, _bit_vector, _and, _result_docs
    { _int, _complex_w_null, _no_values, _similarity_search, _hit_before_last_row, _ve
    { _string, _sequential, _non_existing, _non_equal, _full_result, _bit_vector, _or,
    // ... (more cases left out)
};

//-------------------------------- CODE -------------------------
// first define a fixture class
class TestClass : public ::testing::TestWithParam<t_caseRow>
{
protected:
    virtual void SetUp();
    virtual void TearDown() {};

    void runTest();                 // runs one case of the testCases table
    t_caseRow& _tc;                 // ref to current test case (row)
};
```

parameters and values

cases table

case interpreter
(incl. check code)

Is it worth it?

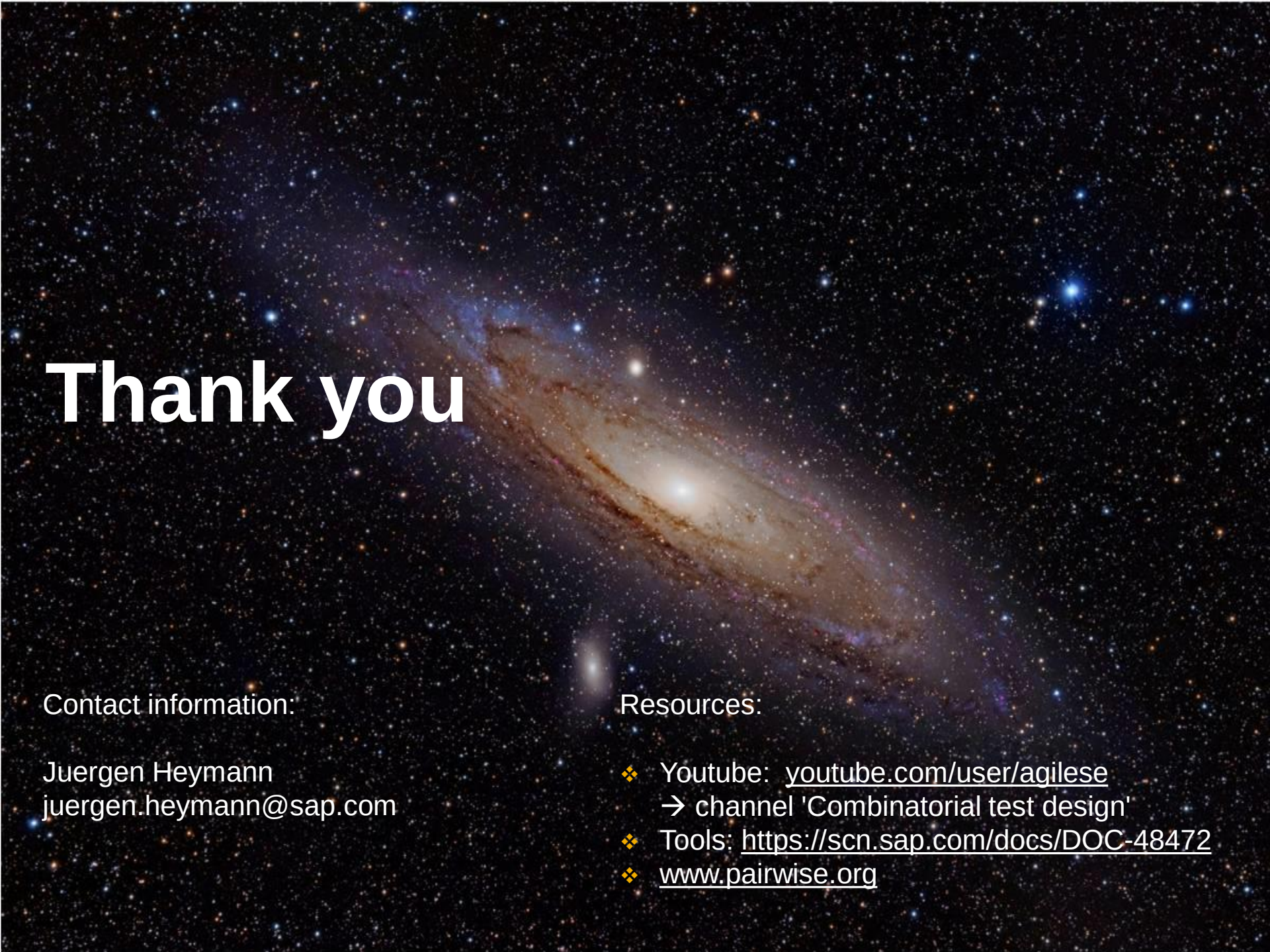
Is it worth it?

Results from 10 applications

- Average of 4x less find-cost-per-defect ('best case' was 10x)
- Modeling effort 1-2 hours per model

Results from Code Example

- 500x less test cases than 'brute force' (=all combinations)
- 100x faster
- 99.6% code coverage (line)



Thank you

Contact information:

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Resources:

- Youtube: youtube.com/user/agilese
  → channel 'Combinatorial test design'
- Tools: https://scn.sap.com/docs/DOC-48472
- www.pairwise.org

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