Autonomous Real-Time Testing for Software & Systems

A Six Sigma Approach

Customer Orientation

Lean Six Sigma

Agile Processes

Project Estimations

Transfer Functions

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Speaker & Authors

Software Models

- Modeling Software by
  - ➔ ISO/IEC 20926 IFPUG
  - ➔ ISO/IEC 19761 COSMIC
  - ➔ Others that are compliant to ISO/IEC 14143….
- Sizing Software according
  - ➔ Functionality
  - ➔ Non-functional Characteristics
  - ➔ Other constraints
- Other models
  - ➔ Unknown degree of granularity
  - ➔ Useless for modeling Security

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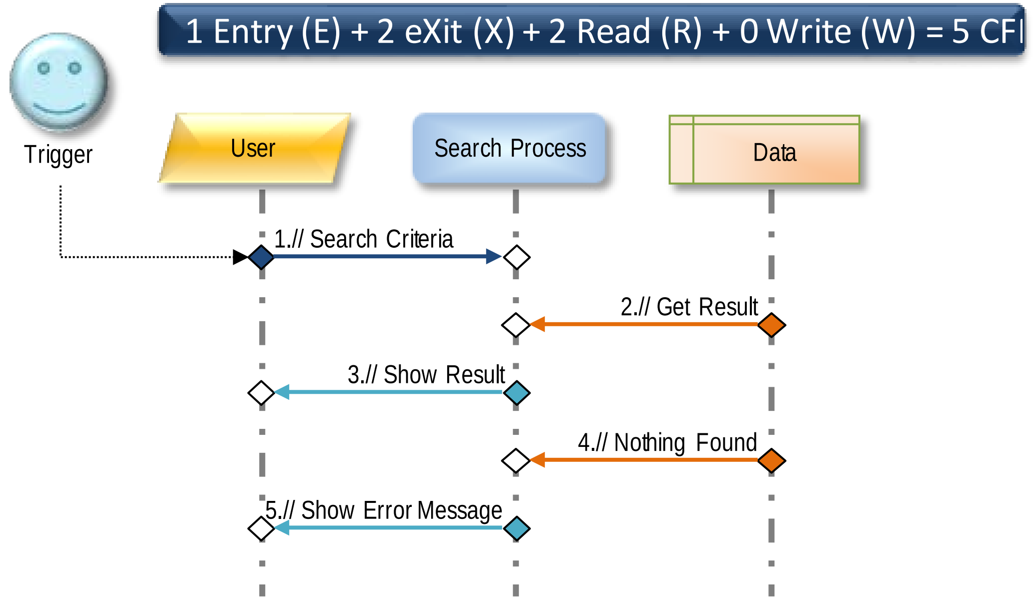
What is an Application?

- **Objects of Interest:**
  - Devices (user or other system)
  - Functional Process
  - Persistent Data
  - Other Applications
- **Data Movements:**
  - Entry
  - eXit
  - Read
  - Write
- Moving **Data Groups** across application within system boundary

Data Movement Map according ISO/IEC 19761 COSMIC



What is a Test?

- A **Software Test** has
  - ➔ Several Test Stories
    - Explaining the Value for the Customer
    - Weighted by **Customer's Priority** for the Test Story
- A **Test Story** has
  - ➔ Many Test Cases
  - ➔ Exploring different aspects – favorable and dismal – of the test story
- A **Test Case** has
  - ➔ Test data and test stubs to run the software under test
  - ➔ An Outcome
    - Passed: all responses according expectations
    - Failed: at least one test case didn't yield the expected response

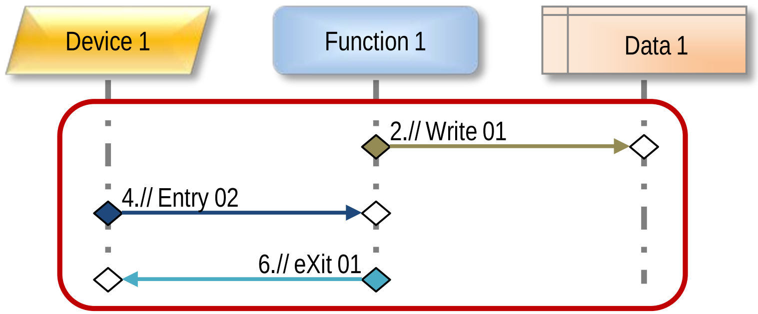
What is a Test Case?

- A **Test Case** has
  - ➔ Entry Data ("Test Data")
    - Explaining the environment for the test case
    - Typically valid, invalid, borderline data
    - Normal and disturbed communication services
  - ➔ A known sequence of data movements executed
    - Defining **Test Coverage** and **Test Size**
  - ➔ Test Size
    - Every Test Case has a size: the number of data movements executed by the test
    - Total Test Size is the number of data movements executed by all test cases
  - ➔ Test Coverage
    - Percentage of data movements covered with test cases

$$\{x_1, x_2, \dots, x_n\} \rightarrow y$$

What is a Test Case?

- Sequence diagrams visualize every test case by its data movements



Test Case Measurements for Test Story Q1-1

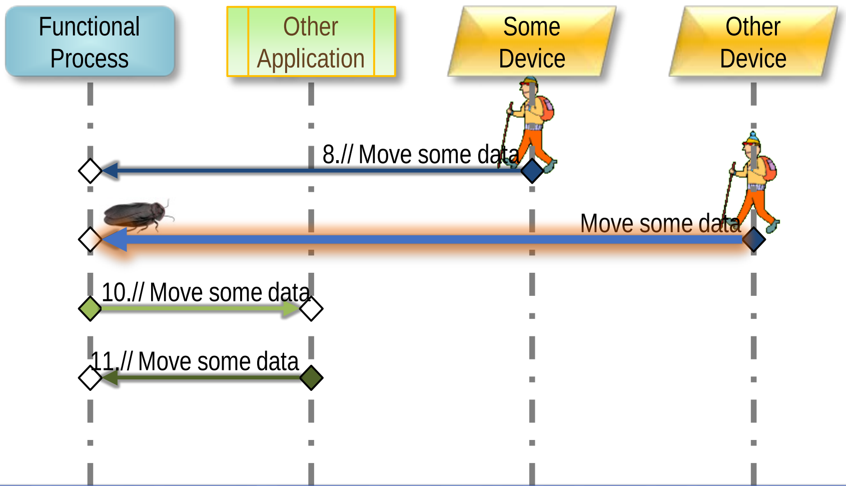
Test Story No. 1

User Stories

Q1-1	*Test Story Q1-1*	Q001: User Story 1	Q002: User Story 2	Q003: User Story 3	*Expected Response*	CFP
Q1-1.1	Test Data Q1-1.1	*X001,W001,E001*			Expected Response Q1-1.1	*3*
Q1-1.2	Test Data Q1-1.2	*X001,E002,W001*	*X006,E007*		Expected Response Q1-1.2	*5*
Q1-1.3	Test Data Q1-1.3	*X005,E005,X003*	*X006,E007*	*X004,E004*	Expected Response Q1-1.3	*7*
	Test Story Contribution (CFP):	*9*	*4*	*2*	*Test Size*	*15*

Functionality, Defect Size, and Defect Density

- What happens if data movements don't work as expected, have defects instead?
- Testers mark and count data movements where defects have been detected
- Same Metric:
  - ➔ ISO/IEC 19761 COSMIC



- Functional Size
  - ➔ Number of Data Movements needed to implement required functionality
- Test Size
  - ➔ Number of Data Movements executed in Tests
- Test Story
  - ➔ Collection of Test Cases aiming at certain FURs
- Defect Count
  - ➔ Number of Data Movements affected by some defect detected in a test story

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Functional Effectiveness

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	IoT Topics	Attributes			Weight	Profile
FUR	y1 Extensible	Easy to extend IoT	Device independent	Flexible	31%	0.57
	y2 Open	Open Source	Open Interfaces		20%	0.36
NFR	y3 Reliable	Always correct	Always secure	Safe	39%	0.71
	y4 Fast	No waiting			11%	0.20

- Establish customer's values regarding IoT Topics
  - ➔ Get a profile using Analytic Hierarchy Process (AHP) or other Voice of the Customer technique
- Look at User Stories and count Data Movements that support some IoT Need
  - ➔ Each Data Movement can support more than one IoT Need

User Stories

IoT Needs		Goal Profile	Q001 Search Data	Q002 Answer Questions	Q003 Keep Data Safe	Achieved Pr[ofile]
y1	Extensible	0.57	4	2	2	0.55
y2	Open	0.36	2	4		0.46
y3	Reliable	0.71	3	4	3	0.67
y4	Fast	0.20	2		1	0.20
Solution Profile for User Stories:			0.65	0.66	0.39	Convergence Gap 0.11

27 Data Moves Covered
0.15 Convergence Range
0.20 Convergence Limit

Count the Data Movements supporting IoT Needs

Test Coverage

Test Cases

Test Story	*Case 1*	*Test Data*	*Expected Response*	*Case 2*	*Test Data*	*Expected Response*	*Case 3*	*Test Data*	*Expected Response*
CT-A.1 Reliable Responses	*CT-A.1.1*	*Enter valid Search String*	*Return (known) Answer*	*CT-A.1.2*	*Enter invalid Search String*	*Invalid Search String*			
CT-A.2 Detect Missing Data	*CT-A.2.1*	*Enter valid Search String for No Data*	*No Data Available*	*CT-A.2.2*	*Enter inv*				
CT-A.3 Data Stays Untouched	*CT-A.3.1*	*Enter valid Search String*	*Return identical Answer*	*CT-A.3.2*	*Enter inv*				

- Collect the data movements that are executed in each test case
  - → If they support one of the user stories, as assessed before, count them!
  - → Data movements are executed more than once
- The Profile for User Stories is used for measuring Test Coverage
  - → The Convergence Gap indicates how well Test Stories cover User Stories

Test Coverage
Deployment Combinator

Test Stories

User Stories	*Goal Test Coverage*	CT-A.1 Reliable Responses	CT-A.2 Detect Missing Data	CT-A.3 Data Stays Untouched	*Achieved Coverage*
Q001 Search Data	*0.65*	5	8	2	*0.64*
Q002 Answer Questions	*0.66*	2	6	8	*0.66*
Q003 Keep Data Safe	*0.39*	4	4	2	*0.40*
Ideal Profile for Test Stories:		*0.43*	*0.74*	*0.51*	*Convergence Gap*

Convergence Gap *0.02*

41 Total Test Size
0.10 Convergence Range
0.20 Convergence Limit

Privacy & Safety Assessment Categories

Table 1. Privacy Assessment Categories.

Privacy Needs	*Privacy Protection*
Value = 0: No privacy. It's public.	Value = 0: No protection. It's public.
Value = 1: Disclosure is inconvenient	Value = 1: Weak encryption
Value = 2: Disclosure can be harmful	Value = 2: Strong encryption
Value = 3: Disclosure costs money	Value = 3: Two-way encryption
Value = 4: Disclosure makes guilty	Value = 4: Data never leaves system
Value = 5: Disclosure threatens lives	Value = 5: Container-protected data

Table 2. Safety Assessment Categories

Incurrence Probability	*Impact*
Value = 0%: No risk. It's safe.	Value = 0: None
Value = 20%: Small probability	Value = 1: Low
Value = 40%: Low medium probability	Value = 2: Little
Value = 60%: High medium probability	Value = 3: Medium
Value = 80%: Very high probability	Value = 4: Quite
Value = 100%: Risk incurred already	Value = 5: High

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Data Movement Table

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Model Elements

Data Movements

	Name	*Label*	*Data Movement Sub-Process Description*	*Effect when Private Data is Disclosed*	*Exposure to Privacy Violation*	*Privacy*	*Probability*	*Impact on Safety*	*Safety*
1)	E001	Search Criteria	Enter search criteria	2: Harmful	5: Internal	5.0	20%	1: Low	0.0
2)	R001	Get Result	See matching results	1: Inconvenient	3: Two-way	3.1	10%	2: Little	0.6
3)	X001	Show Result	Display results	1: Inconvenient	3: Two-way	3.1	10%	2: Little	0.6
4)	R002	Nothing Found	Explain that no data matches search criteria	1: Inconvenient	5: Internal	5.0	10%	2: Little	0.6
5)	X002	Show Error Message	Explain it to the user	1: Inconvenient	5: Internal	5.0	10%	1: Low	0.0
6)	E003	Enable Sensors	Switch IoT network on	2: Harmful	4: Enclosed	4.3	33%	1: Low	0.3
7)	X003	Switch Sensor on	Tell sensor what data to collect	2: Harmful	4: Enclosed	4.3	33%	1: Low	0.3
8)	E002	Sensor Data	Collected data	2: Harmful	4: Enclosed	4.3	33%	1: Low	0.3
9)	W002	Data Recording	Collected data saved to persistent store	4: Makes guilty	5: Internal	5.0	0%	1: Low	0.0
10)	R003	Sensor Statistics	Aggrgated sensor data	2: Harmful	5: Internal	5.0	20%	2: Little	0.6
11)	X004	Dashboard	Show sensor data	1: Inconvenient	5: Internal	5.0	20%	2: Little	0.6

Add Row | Ins Row | Del Row | Validate | Extract | SNAP

Privacy Index: 5.0
Safety Index: 0.3
Minimum Privacy: 3.1
Maximum Risk: 0.6

Model Implementation

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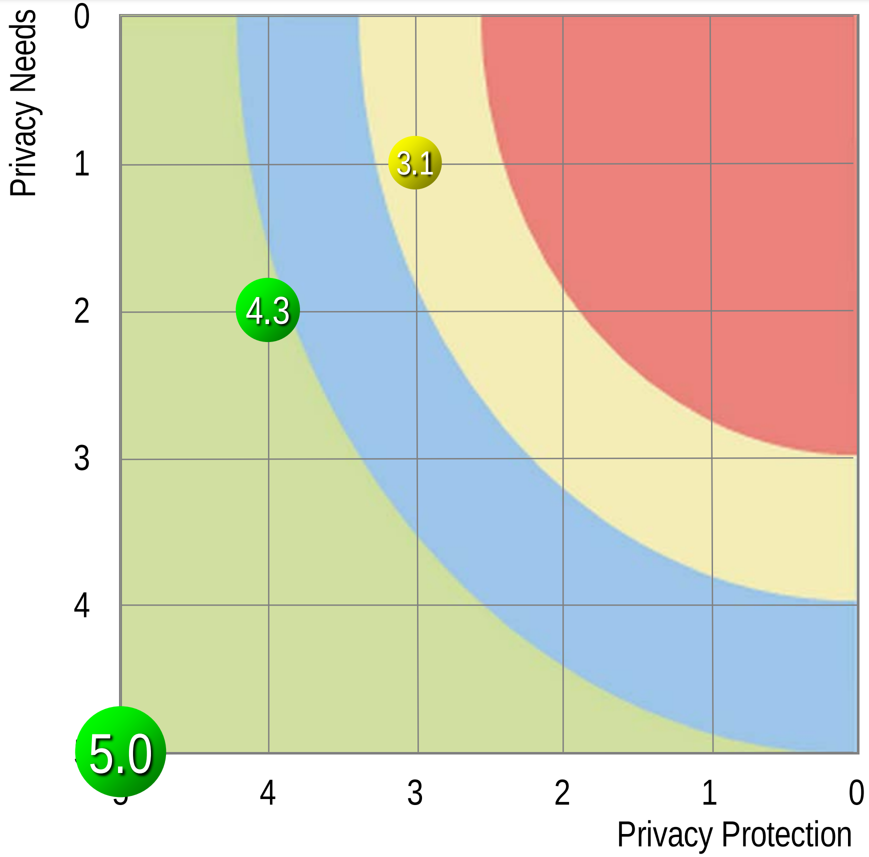
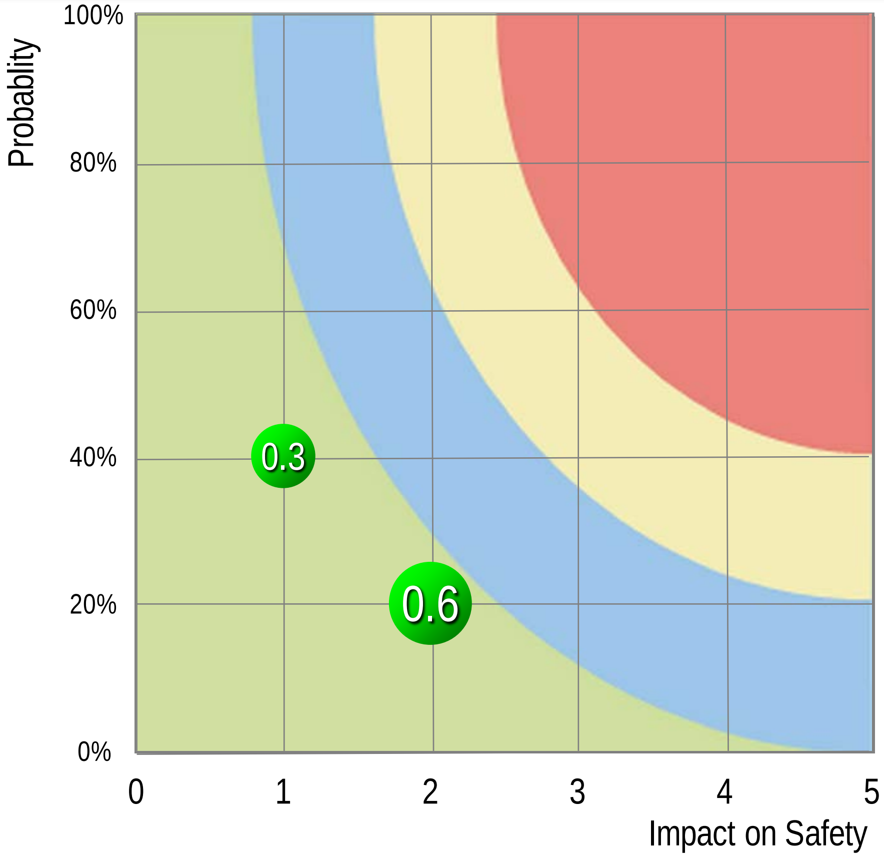
Privacy and Safety Metrics – Consumer Display



- Low Privacy Index
- Medium Privacy Index
- High Privacy Index
- Good Privacy Index

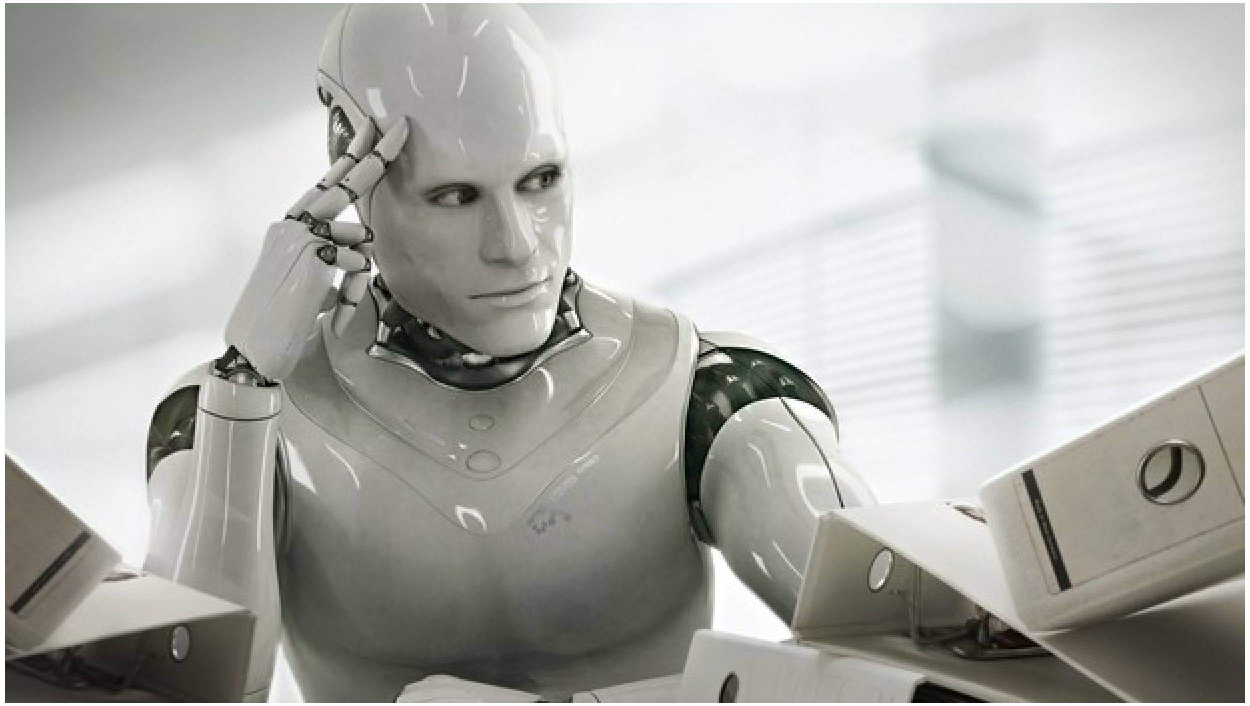


- Major Safety Risk
- High Safety Risk
- Medium Safety Risk
- Low Safety Risk

Testing Automation

- What is the purpose of the Convergence Gap?
  - ➔ It allows for automated creation of meaningful test cases
  - ➔ The software provider has only to furnish the user stories and test stories with an initial, potentially incomplete set of test cases

- What means “Digitalization”?
  - ➔ Products become software-intense
  - ➔ Products adapt to Customer Needs

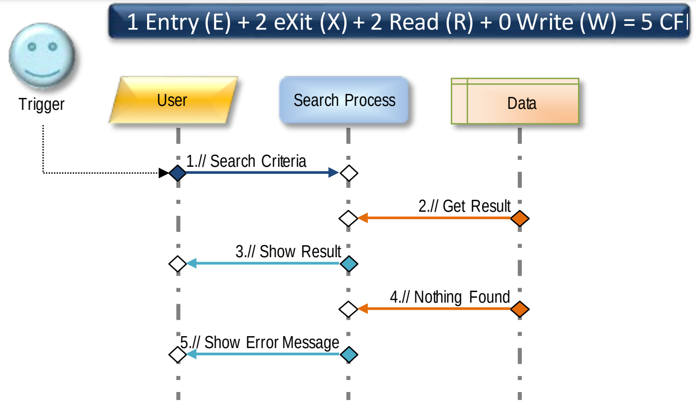


How can Things become Intelligent?

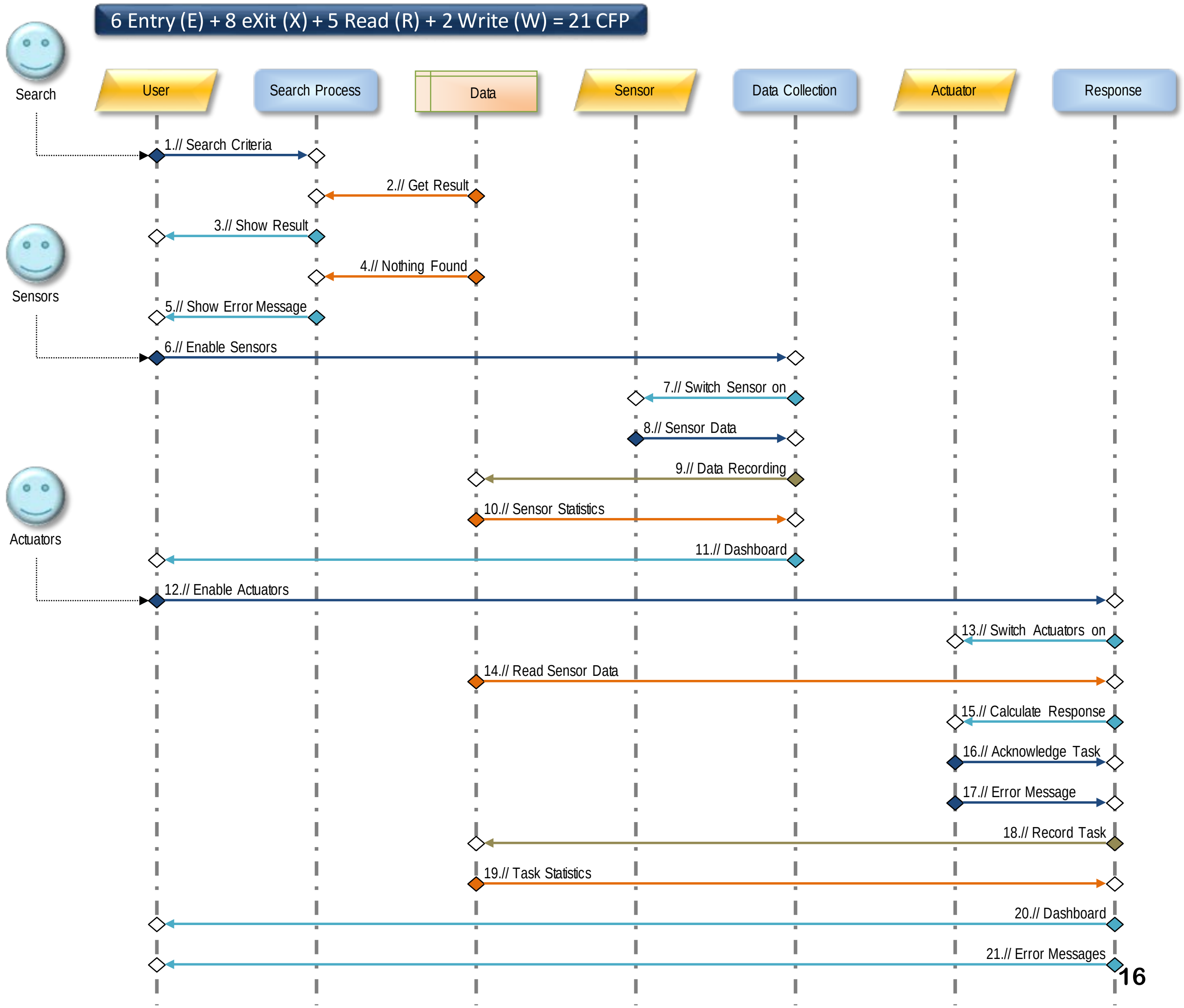
- Like intelligent beings should, prepare actions by simulating the effects produced when taking them – without actually executing them
  - ➔ This means, execute a software test before putting decisions to actions
  - ➔ The decision alternatives are the test cases; actions considered for execution are the test stubs
- Test the outcome of actions
  - ➔ Record the test outcomes
  - ➔ Assess the effect of decisions
  - ➔ Then take actions
- However…

Where do the Tests Cases come from?

Add an IoT Concert

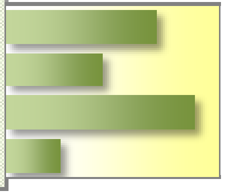


- Add sensors and actuators
- Collect data
- Enhance search results by actually observed data



IoT Needs remain; Functional Effectiveness evolves

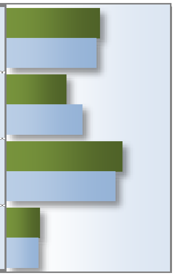
	IoT Topics	Attributes			Weight	Profile
FUR	y1 Extensible	Easy to extend IoT	Device independent	Flexible	31%	0.57
	y2 Open	Open Source	Open Interfaces		20%	0.36
NFR	y3 Reliable	Always correct	Always secure	Safe	39%	0.71
	y4 Fast	No waiting			11%	0.20



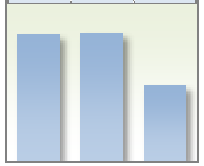
IoT Needs
Deployment Combinator

User Stories

IoT Needs		Goal Profile	Q001 Search Data	Q002 Answer Questions	Q003 Keep Data Safe	Achieved Profile
y1	Extensible	0.57	4	2	2	0.55
y2	Open	0.36	2	4		0.46
y3	Reliable	0.71	3	4	3	0.67
y4	Fast	0.20	2		1	0.20
Solution Profile for User Stories:			0.65	0.66	0.39	Convergence Gap 0.11



27 Data Moves Covered
0.15 Convergence Range
0.20 Convergence Limit

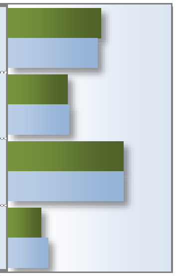


IoT Needs
Deployment Combinator

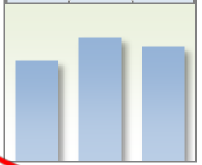
User Stories

IoT Needs		Goal Profile	Q001 Search Data	Q002 Answer Questions	Q003 Keep Data Safe	Achieved Profile
y1	Extensible	0.57	9	12	10	0.55
y2	Open	0.36	7	10	4	0.37
[illegible]	[illegible]	0.71	11	13	16	0.71
[illegible]	Fast	0.20	6	4	4	0.24
Solution Profile for User Stories:			0.51	0.63	0.59	Convergence Gap 0.04

Changed!



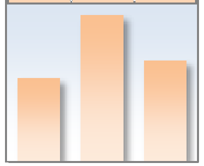
106 Data Moves Covered
0.10 Convergence Range
0.20 Convergence Limit



Test Coverage for the Full IoT Concert

Test Coverage
Deployment Combinator

User Stories	*Goal Test Coverage*	CT-A.1 Reliable Responses	CT-A.2 Detect Missing Data	CT-A.3 Data Stays Untouched	*Achieved Coverage*
Q001 Search Data	0.65	5	8	2	0.64
Q002 Answer Questions	0.66	2	6	8	0.66
Q003 Keep Data Safe	0.39	4	4	2	0.40
Ideal Profile for Test Stories:		0.43	0.74	0.51	*Convergence Gap* 0.02



41 Total Test Size
0.10 Convergence Range
0.20 Convergence Limit

Test Coverage
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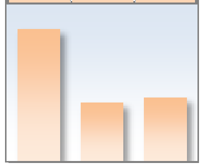
User Stories	*Goal Test Coverage*	CT-A.1 Reliable Responses	CT-A.2 Detect Missing Data	CT-A.3 Data Stays Untouched	*Achieved Coverage*
Q001 Search Data	0.51	23	14	4	0.52
Q002 Answer Questions	0.63	26	11	10	0.60
Q003 Keep Data Safe	0.59	23	7	20	0.60
Ideal Profile for Test Stories:		0.84	0.37	0.41	*Convergence Gap* 0.03



138 Total Test Size
0.10 Convergence Range
0.20 Convergence Limit

- Automatic selection of additional test cases based on
  - ➔ Same Test Stories
  - ➔ Analogous Sensor Entries and Responses
  - ➔ Keep Convergence Gap → 0 as the selection criterion

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Sample Privacy Evolution

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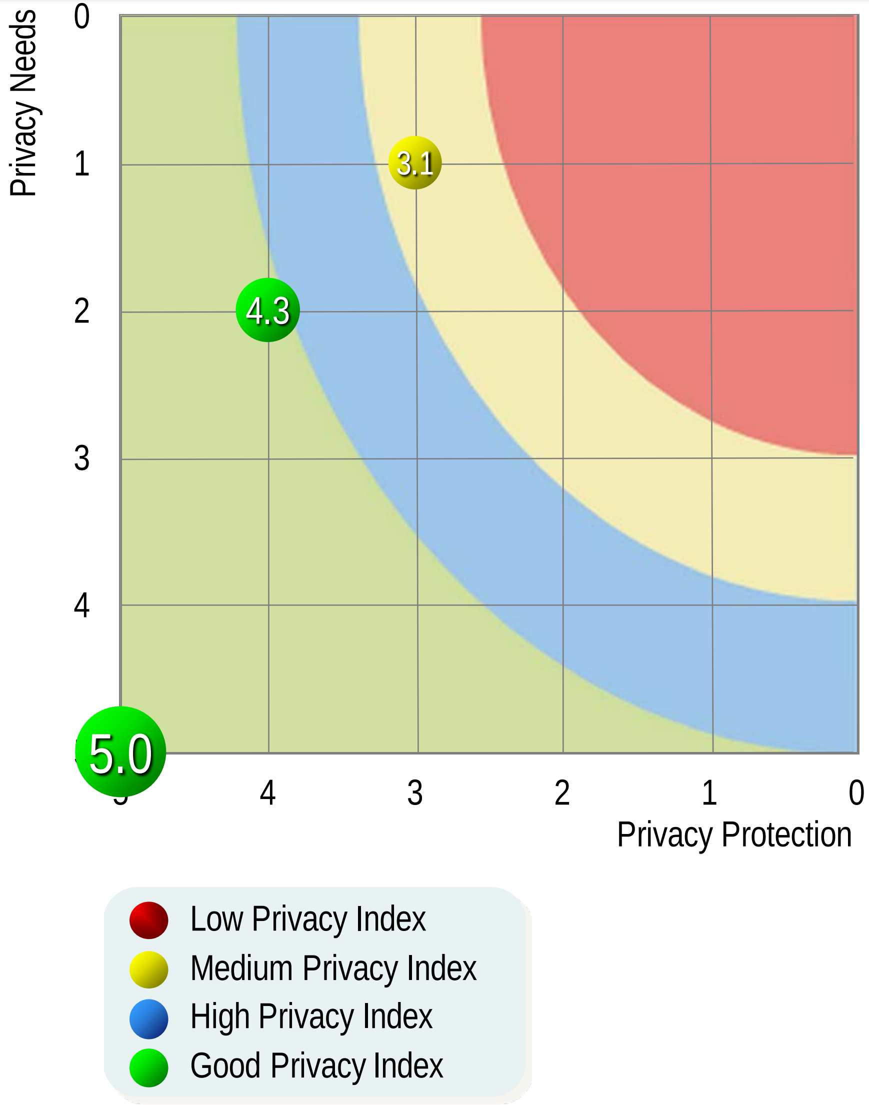
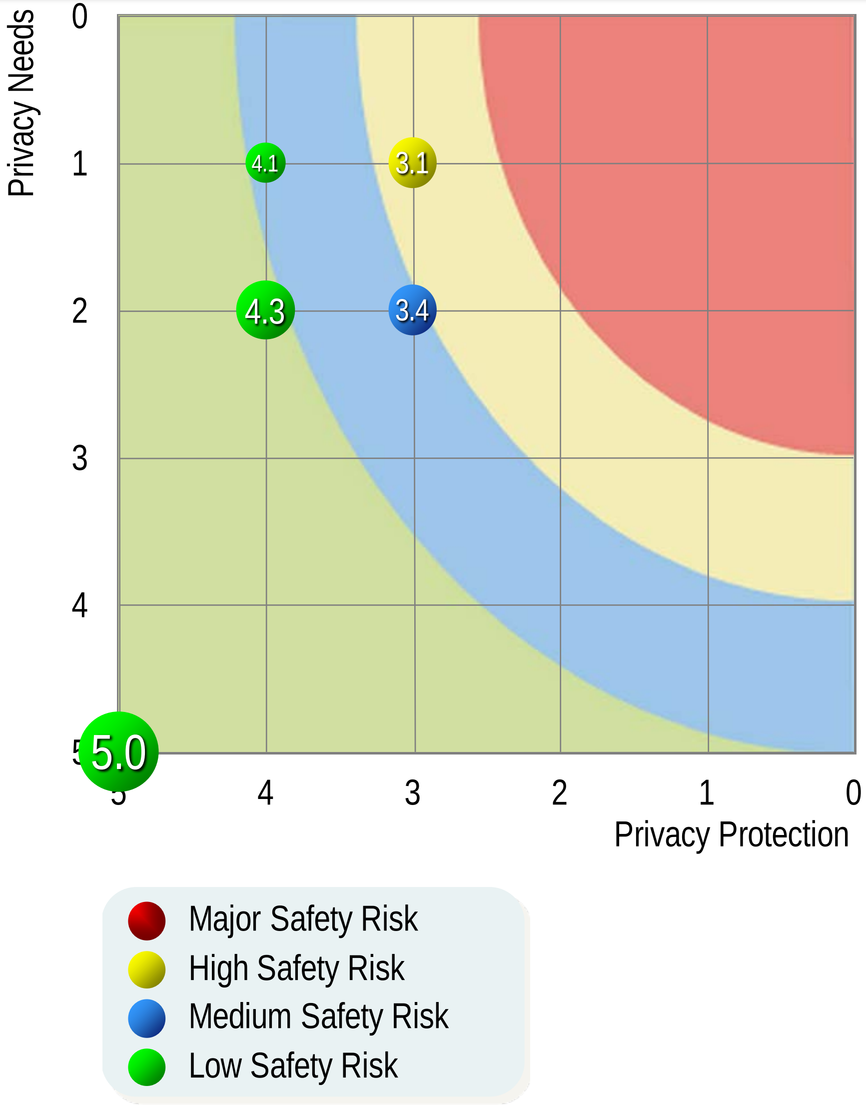


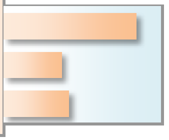


The Fully Extended Test Cases for the IoT Concert

Test Cases

Test Story	Case 1	Test Data	Expected Response	Case 2	Test Data	Expected Response	Case 3	Test Data	Expected Response	Case 4	Test Data	Expected Response
CT-A.1 Reliable Responses	CT-A.1.1	Enter valid Search String	Return (known) Answer	CT-A.1.2	Enter invalid Search String	Invalid Search String	CT-A.1.3	Sensor Readings	Retrieved in Database	CT-A.1.4	Transmission Error	No Data available
CT-A.2 Detect Missing Data	CT-A.2.1	Enter valid Search String for No Data	No Data Available	CT-A.2.2	Enter invalid Search String	Invalid Search String	CT-A.2.3	Sensor Off	No Data available	CT-A.2.4	Sensor Off	Dashboard Indication
CT-A.3 Data Stays Untouched	CT-A.3.1	Enter valid Search String	Return identical Answer	CT-A.3.2	Enter invalid Search String	Invalid Search String	CT-A.3.3	Enter same String Again	Return identical Answer	CT-A.3.4	Transmission Interference	Data Rejected

Case 4	Test Data	Expected Response	Case 5	Test Data	Expected Response	Case 6	Test Data	Expected Response	Case 7	Test Data	Expected Response	Priority Weight	Profile	Test Size
CT-A.1.4	Transmission Error	No Data available	CT-A.1.5	Actuator Enabled	Dashboard Indication	CT-A.1.6	Actuator Off	No Action	CT-A.1.7	Actuator Response	Stored in Database	49%	0.84	72
CT-A.2.4	Sensor Off	Dashboard Indication	CT-A.2.5	Actuator Off	Dashboard Indication	CT-A.2.6	Invalid Actuator Data	No Action	CT-A.2.7	Invalid Actuator Data	Dashboard Indication	21%	0.37	32
CT-A.3.4	Transmission Interference	Data Rejected	CT-A.3.5	Actuator Set	Actuator does it	CT-A.3.6	Transmission Interference	No Action	CT-A.3.7	Transmission Interference	Dashboard Indication	24%	0.41	34



- Test intensity now moves towards reliability
  - ➔ Quite typical when adding an IoT concert to some existing software
  - ➔ All remains measurable
  - ➔ And autonomous things become comparable in terms of safety, privacy, or whatever affects customer's needs

The Issue of Real-Time

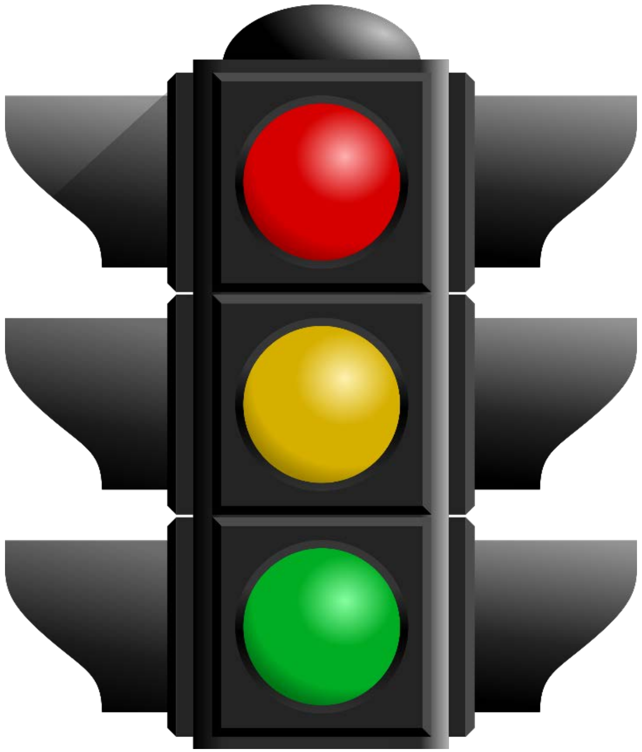
Straight-forward!

- **Real-Time doesn't mean:**
  - ➔ "If a child runs behind his ball across the street, test whether breaking helps"
  - ➔ This is too late for testing; only immediate action avoids damage
- **Real-Time means:**
  - ➔ If my car drives through a new settlement, not yet on the map, and perceives the possibility of children not taking care for traffic, my car tests the distances for visual detection of obstacles crossing its way, eventually reducing speed
  - ➔ Autonomous testing is a background process that enables my autonomous car to drive safely through streets, even if an accurate map is missing
  - ➔ Autonomous testing starts when something unknown or unexpected is encountered
  - ➔ Autonomous real-time testing uses some already existing rule set prepared for driving through a settlement that has open access to streets, expecting playing children
  - ➔ Autonomous Real-time Testing is **Learning when Needed, Adapting to new Environments**

The Vision

- Generate more Test Cases when needed
  - ➔ In real-time; within a limited time frame
  - ➔ Belonging to an existing Test Story
  - ➔ Based on existing test patterns

- Execute autonomous real-time tests in the background
  - ➔ Test Results might affect behavior
  - ➔ Results come as by Test Measurements
  - ➔ Indicating green-yellow-red depending on Test Results

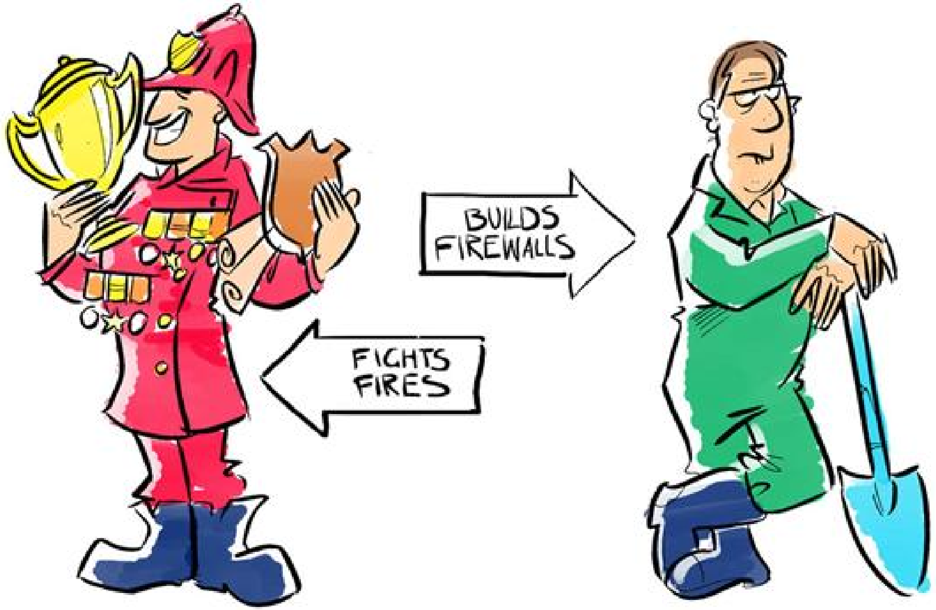


Unresolved Problems and Weaknesses

- The main weakness of the approach is
  - ➔ How are data movements associated to specific customer's needs?
  - ➔ This is a non-automatic process, depending from developers' expertise about customer's values and business drivers
  - ➔ Agile teams are used to assess business value, but not on the data movement level
- Many data movements serve more than one user story
- Association of data movements to user stories is crucial for creating and evaluating test cases automatically
  - ➔ When establishing Functional Effectiveness, you can trick somewhat
  - ➔ Is this safe for extending Test Cases?
  - ➔ How fast can Artificial Intelligence extend Test Cases and select the right ones?

Unresolved Problems and Weaknesses

- COSMIC counts are not mainstream
  - ➔ Important code quality tools such as SonarQube do not (yet) count functional size automatically
  - ➔ Testing metrics are virtually unknown
  - ➔ Customers do not understand neither size nor test metrics
  - ➔ The current hype for autonomous car driving hides the need for safety and privacy
- Approach is not easily carried over to ISO/IEC 20926 IFPUG Function Points



Conclusions

- Autonomous Real-Time Testing is something immediately needed that will become highly important in the near future
  - → Autonomous cars never will hit the roads without autonomous real-time tests
  - → IoT is bound for failure without autonomous real-time tests
  - → ICT's future is in jeopardy without autonomous real-time tests

- It's a good idea to get acquainted with the concept early enough
  - → Autonomous things need Software Metrics!
  - → Measure Software Tests!

Questions?

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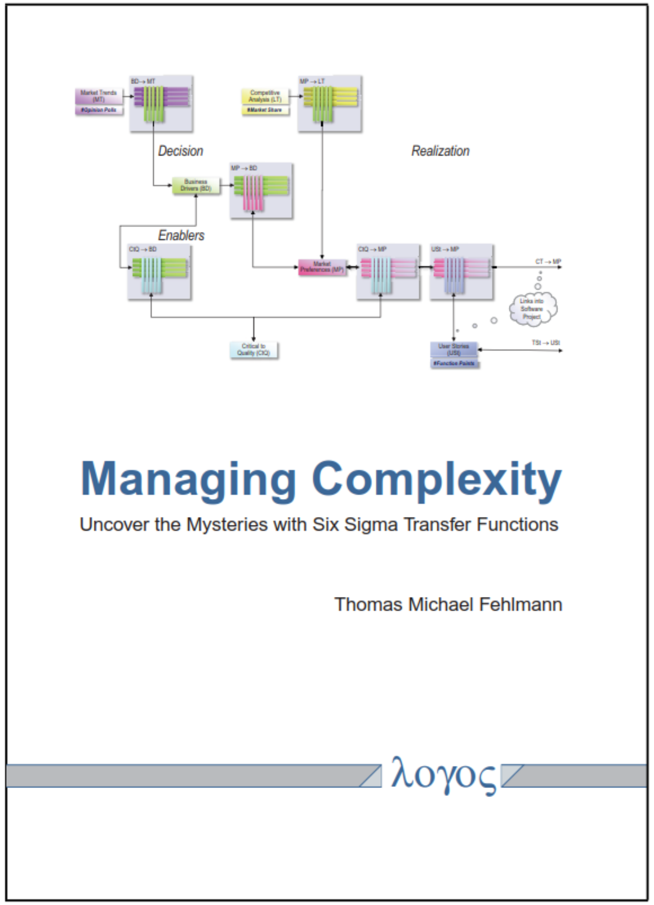
New Book on Six Sigma Transfer Functions



Managing Complexity

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