

AI and Cause-Effect Chains – Can QFD Help?

Customer Orientation

 Lean Six Sigma

 Agile Processes

 Project Estimations

 Transfer Functions



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AI and QFD share a common ancestry: the Perceptron, a collection of Ichikawa fishbone diagrams that somehow describe dependency. The perceptron was a very simple model of how neural networks think.

The original perceptron proved to be much too small to compete with natural thinking, but good enough to study cause-effect relationships between customer needs and technical characteristics.

In contrast to the perceptron, QFD became a mighty tool in the Eighties. It allowed expert teams that knew the current domain to identify the causes that make a product successful in the market and to target products predictably to cover customer needs.


But in the 21st century, preferences have changed and people care more about social standing and reputation than about actual benefit. Collecting big data that can be processed by even bigger perceptrons – called Large Language Models (LLM) – replace at least partially the former QFD cause/effect analysis. With enough data, it seems that the only remaining relevant cause is adoption by enough people.

However, this works only partially. Expectations for future profits only partially cover today's real cost, and the famous AI that should process these big data collections unfortunately hallucinate. This happens because AI does not know anything about the current domain.

Thus, the question arises whether we cannot take the best of both sides and complement AI by sound cause/effect analysis with QFD.

This Café is about successful cases but also about strong barriers that make such common work difficult. Nevertheless, we also give indications on how to overcome such barriers.

QFD



Speaker & Authors


Customer Orientation

 Lean Six Sigma

 Agile Processes


 Project Estimations

 Transfer Functions



- Dr. Math ETHZ
- Quality Function Deployment (QFD)
- Six Sigma for Software
- Testing Complex Systems
- Representing Knowledge in Artificial Intelligence
- Measuring Software & Knowledge
- Quality Management for Product Development

Thomas M. Fehlmann
Zürich



- Mathematics and Computer Science
- Emphasis on Mathematical Statistics
- Mathematical Optimization
- Six Sigma Black Belt for Software Development
- Software Quality Assurance Manager

Eberhard Kranich
Duisburg

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Thomas Fehlmann, Zurich

Dr. Thomas Fehlmann is an expert in software metrics and testing, a Lean Six Sigma Black Belt for agile software development and a promoter of customer-centric product design and testing. As a quality manager for software companies, he has led several companies to global market leadership using Quality Function Deployment (QFD) and Six Sigma for software.

He is Academic Member of the Athens Institute for Education and Research.

Eberhard Kranich, Duisburg

Eberhard Kranich studied Mathematics and Computer Science, with an emphasis on Mathematical Statistics, Mathematical Optimization, and on Theory of Polynomial Complexity of Algorithms.

He worked at T-Systems International GmbH in Bonn, Germany until 2013, as a Six Sigma Black Belt and Quality Assurance Manager, mainly in the context of software development.

QFD



Goals of this Presentation

Customer Orientation

 Lean Six Sigma

 Agile Processes


 Project Estimations

 Transfer Functions

- 1) *QFD is not a thing of the past but essential for AI*

- 2) *Motivate you to grow from a QFD expert to become an AI expert*

- 3) *Looking at history of AI and QFD: Same origins, same goals, similar hurdles*



“In God we Trust,
 all others must bring data”
(Edward Deming, Grandfather of Lean.)

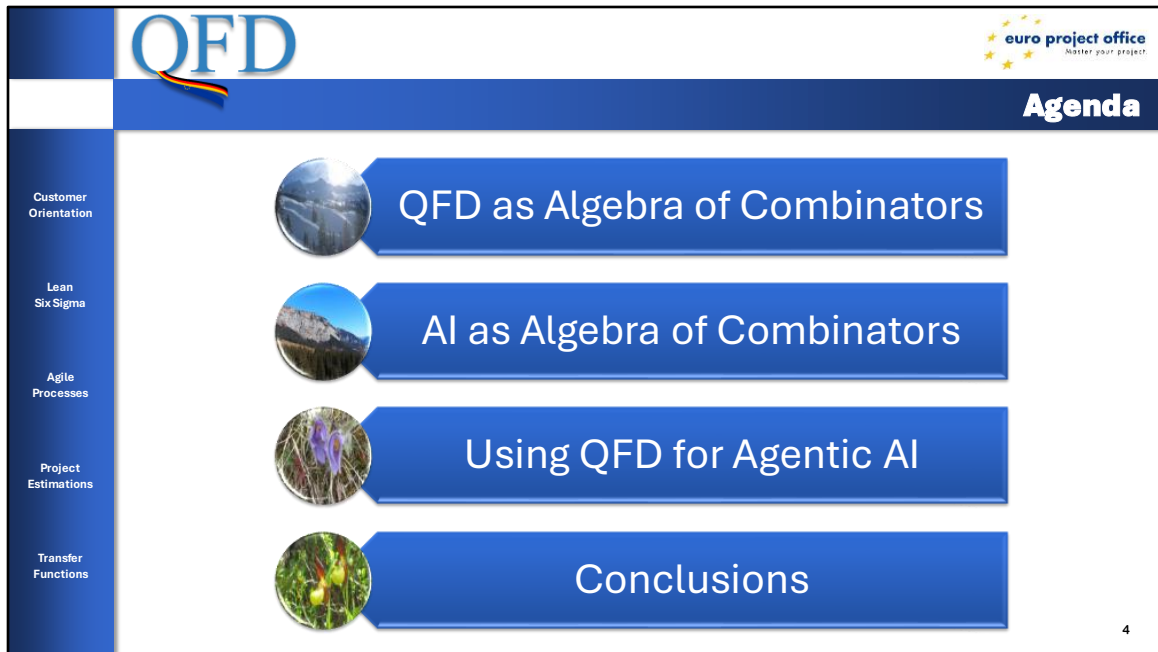
3

The focus on ISO 19761 COSMIC is due to the popularity of COSMIC when sizing embedded software. Any other sizing method can be adapted as well, if allowing for a little imprecision for not being compliant to the VIM and the GUM.

The VIM: ISO/IEC Guide 99:2007 International Vocabulary of Metrology – Basic and general concepts and associated terms (Vocabulaire International de Métrologie – VIM)

The GUM: ISO/IEC CD Guide 98-3, 2015. Evaluation of measurement data – Part 3: Guide to Uncertainty in Measurement (GUM).

The VIM and the GUM are among the oldest standards that the world uses. In simple words: You can add & subtract measurements, like you can measure distance between several points in space, and get the total distance, possibly after some trigonometric adjustments.

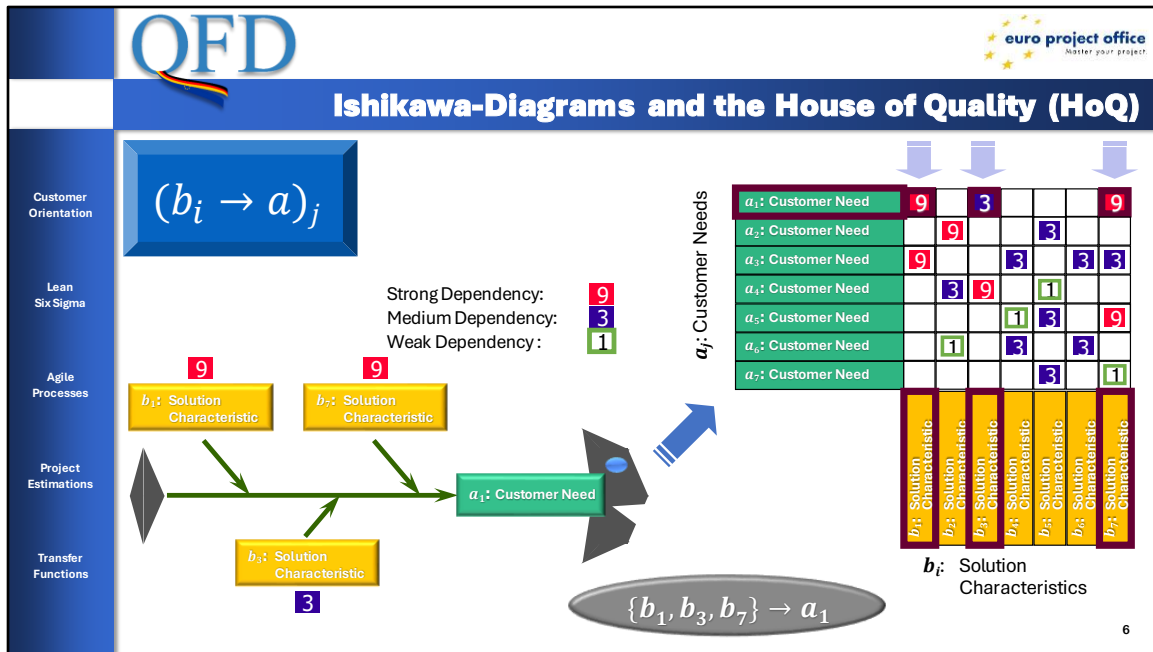


The slide features a blue header with the 'QFD' logo on the left and the 'euro project office' logo on the right. Below the header is a dark blue bar with the word 'Agenda' in white. On the left side, there is a vertical blue bar containing the text: 'Customer Orientation', 'Lean Six Sigma', 'Agile Processes', 'Project Estimations', and 'Transfer Functions'. The main content area contains four blue horizontal bars, each with a circular image on the left and text on the right. The items are: 1. A landscape image with the text 'QFD as Algebra of Combinators'. 2. A mountain landscape image with the text 'AI as Algebra of Combinators'. 3. A purple flower image with the text 'Using QFD for Agentic AI'. 4. A green plant image with the text 'Conclusions'. A small number '4' is located in the bottom right corner of the slide.

- QFD as Algebra of Combinators
- AI as Algebra of Combinators
- Using QFD for Agentic AI
- Conclusions

The slide features a blue and white color scheme. At the top left, the letters 'QFD' are displayed in a large, blue, serif font. To the right, the 'euro project office' logo is visible, consisting of three yellow stars and the text 'euro project office' with the tagline 'Master your project' below it. The word 'Agenda' is written in a bold, white, sans-serif font in the top right corner. A large blue horizontal bar contains the main title 'QFD as Algebra of Combinators' in white, sans-serif font. To the left of this bar is a circular image of a snowy mountain landscape. Below the main title bar, three smaller blue horizontal bars are stacked vertically, each preceded by a circular image: a mountain landscape, purple flowers, and a green parrot. The sidebar on the left contains a vertical menu with the following items: 'Six Sigma', 'Agile Processes', 'Project Estimations', and 'Transfer Functions'. The number '5' is located in the bottom right corner of the slide.

- QFD as Algebra of Combinators
- AI as Algebra of Combinators
- Using QFD for Agentic AI
- Conclusions



In 2001, Fehlmann presented a paper at the 7th International Symposium for Quality Function Deployment on “QFD as Algebra of Combinators” that was widely not understood. Its content said that QFD constitutes a model for combinatory logic; however, who knew combinatory logic? Combinatory logic is a foundation of computer science, explaining how programs rely on a quantifier-free logical structure that is Turing-complete but has the charming aspect that it looks so complicated that it only appeals to mathematical nerds.


Nevertheless, it was a simple observation looking at the origins of QFD as a matrix-representation of a series of Ishikawa-, or Fishbone-Diagrams. Such diagrams are of the form

$$b_i \rightarrow a$$

Here, b_i is a finite set of causes; a is the observable response.

Moreover, a set of Ishikawa-Diagrams that refer to the same topics can be written as a matrix.

QFD



Example: Improving Call Center Services with Classic QFD

Customer Orientation

 Lean Six Sigma

 Agile Processes

 Project Estimations

 Transfer Functions

- Ishikawa diagrams for identifying cause and effect
 - ➔ Expected response should satisfy customer's needs

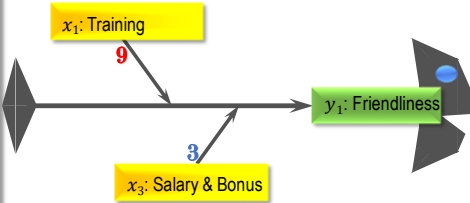
- With many causes and effects
 - ➔ Matrix is handier
 - ➔ Quality Function Deployment (QFD)

Critical To Quality Deployment Combinator

		Critical To Quality			
		x1 Training	x2 ICT Infrastructure	x3 Salary & Bonus	x4 Work Place
Expected Response	y1 Friendliness	0.69	9	3	
	y2 Responsiveness	0.56	9	7	
	y3 Accuracy	0.45	1	5	3

Solution Profile for Critical To Quality: 0.62 0.47 0.40 0.49

37 Total Effort Points
 0.10 Convergence Range
 0.20 Convergence Limit




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Ishikawa diagrams (also called fishbone diagrams, herringbone diagrams, cause-and-effect diagrams, or Fishikawa) are causal diagrams created by Kaoru Ishikawa (1968) that show the causes of a specific event, or response of a system. Common uses of the Ishikawa diagram are product design and quality defect prevention to identify potential factors causing an overall effect. Each cause or reason for imperfection is a source of variation.

In case the single fish becomes a huge fish swarm, matrices proved to be handier. This was the advent of *Quality Function Deployment (QFD)*.

Different causes, or controls, produced effects, or responses, at different strengths. Often, the strength, or correlation, is not fixed but can be varied, as in this example, where four controls are used to produce three responses in a call-in help desk system. You can train the people, improve ICT infrastructure, increase salary and bonus depending on success, or propose better workplaces, for improving call-in service.

QFD



Example: Improving Call Center Services with Classic QFD

Customer Orientation

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 Project Estimations

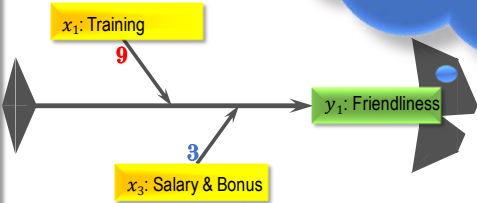
 Transfer Functions

- Ishikawa diagram for cause and effect
 - ➔ Expected response customer's need

- With many causes
 - ➔ Matrix is handled
 - ➔ Quality Function Deployment



Yoji Akao
Professor at
Yamanashi University and
Tamagawa University, Japan




Critical To Quality				
	x1 Training	x2 ICT Infrastructure	x3 Salary & Bonus	x4 Work Place
Accuracy	0.69	9	3	
Efficiency	0.56	9	7	
Availability	0.45	1	5	3
Convergence Profile for Critical To Quality:				
	0.62	0.47	0.40	0.49

37 Total Effort Points
 0.10 Convergence Range
 0.20 Convergence Limit

Yoji Akao (赤尾 洋二, Akao Yōji, 1928 – October 24, 2016) was a Japanese planning specialist recognized as the developer of Hoshin Kanri (a strategic planning methodology). With the late Shigeru Mizuno, he developed Quality Function Deployment (a group decision making technique). Akao and Mizuno also co-founded the **Quality Function Deployment Institute**: a non-profit organization dedicated to dissemination and advancement of QFD.

QFD



Solution with Eigenvectors

Customer Orientation

 Lean Six Sigma

 Agile Processes

 Project Estimations

 Transfer Functions

- How to make sure that the identified solution profile delivers the expected response?
 - ➔ Mathematically speaking, $x = A^{-1}y$ is not a solution for $y = Ax$
 - ➔ This is how people used to interpret QFD matrices in the early times

- Close the Convergence Gap by shifting focus from Salary & Bonus to more accurate ICT Infrastructure
 - ➔ Eigenvector method yields solutions that are mathematically sound

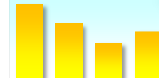
Critical To Quality Deployment Combinator

		Goal Profile	Critical To Quality				Achieved Profile
			x1 Training	x2 ICT Infrastructure	x3 Salary & Bonus	x4 Work Place	
Expected Response							
y1	Friendliness	0.69	9		2		0.69
y2	Responsiveness	0.56		7		5	0.58
y3	Accuracy	0.45	1	2	4	3	0.43

Solution Profile for Critical To Quality: 0.68 0.50 0.32 0.43 Convergence Gap 0.03

33 Total Effort Points

0.10 Convergence Range
 0.20 Convergence Limit



y_E is the Eigenvector of AA^T

$y \approx Ax$

$x = A^{-1}y$

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Thanks to the Eigenvector method, it becomes possible to detect missing solution elements such as here the wrong focus on Salary & Bonus instead of improving the ICT Infrastructure.

Note that the total effort, i.e., cost, also decreased. As small this example might be, it shows quite clearly that QFD quite often does not behave as expected but yields surprising results, same as Saaty's AHP does, from where we inherited the Eigenvector method.

QFD

$M \bullet N = \{b | \exists a_k \rightarrow b \in M, a_k \subset N\}$

Master your project

Comprehensive QFD

Customer Orientation

 Lean Six Sigma

 Agile Processes

 Project Estimations

 Transfer Functions

- $(b_i \rightarrow a) \bullet \left((c_j \rightarrow b) \bullet \left((d_k \rightarrow c) \bullet \left((e_s \rightarrow d) \bullet (e) \right) \right) \right)$
- ➔ $(b_i \rightarrow a)$ is the House Of Quality
- ➔ $(c_j \rightarrow b)$ the Solution Characteristics deployment
- ➔ $(d_k \rightarrow c)$ the Methods & Tools selection
- ➔ $(e_s \rightarrow d)$ the Vendor Selection

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A comprehensive QFD deployments in the traditional manner is a cascading application operation between knowledge as follows:

$$(b_i \rightarrow a) \bullet \left((c_j \rightarrow b) \bullet \left((d_k \rightarrow c) \bullet \left((e_s \rightarrow d) \bullet (e) \right) \right) \right)$$

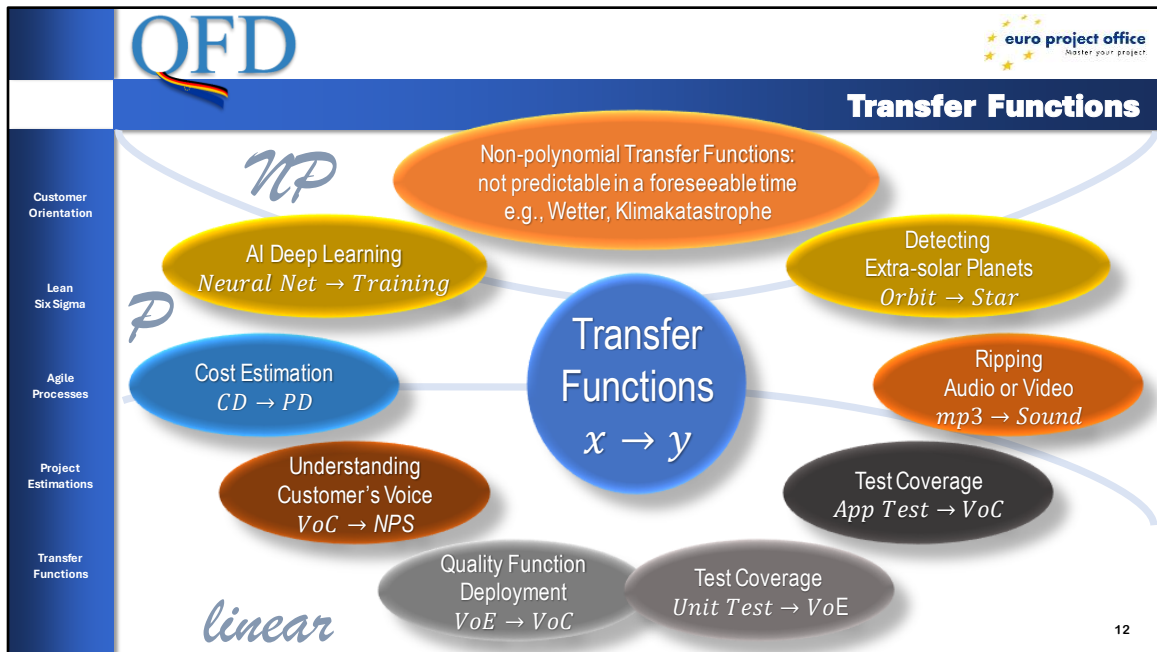
where $(b_i \rightarrow a)$ is the House Of Quality, $(c_j \rightarrow b)$ the Solution Characteristics deployment, $(d_k \rightarrow c)$ the Methods & Tools selection, $(e_s \rightarrow d)$ the Vendor Selection; and where (e) is the set of vendors, (d) the methods & tools, (c) the solution design, (b) the solution characteristics, and (a) the customer's needs.

Using the abbreviations in the above figure, the arrow scheme equation reads as

$$(EC_i \rightarrow CN) \bullet \left((SD_j \rightarrow EC) \bullet \left((PP_k \rightarrow SD) \bullet \left((VS_s \rightarrow PP) \bullet (VS) \right) \right) \right)$$

If you think this simplistic example is complicated, read again Akao's Big Black Book from 1990!

What matters is that the QFD process is applicable to other QFD processes. It is a combinatory algebra, with recursiveness.

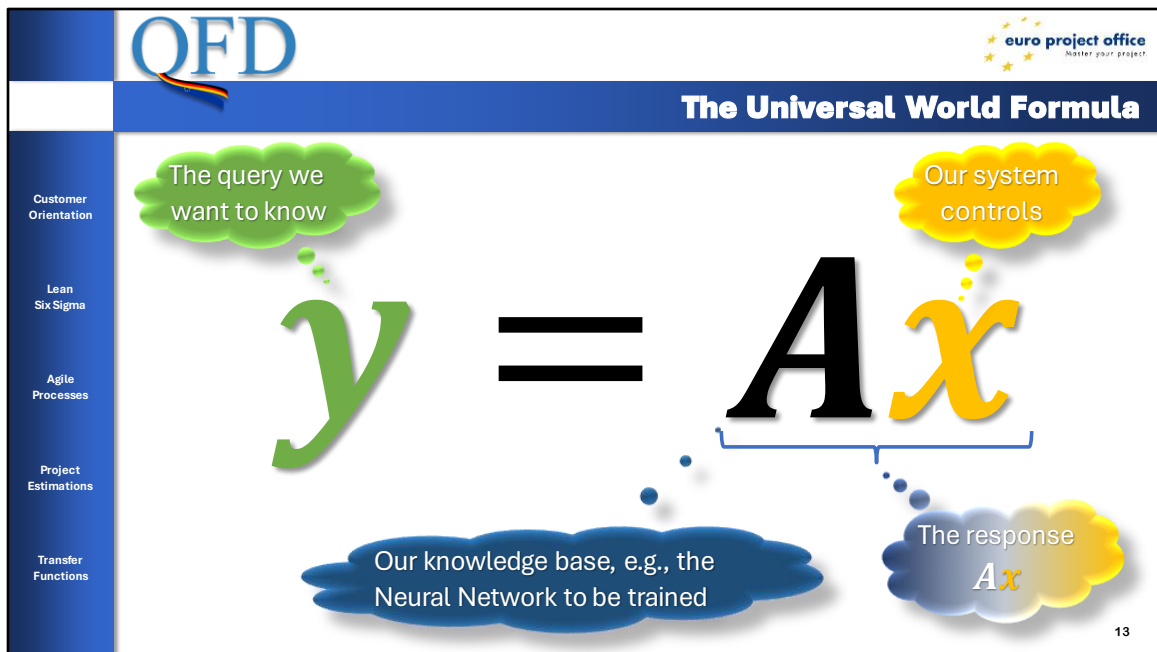


What was the most important invention of the 20th century??

The proof that the *Fast Fourier Transform* (FFT) is not NP-complete had the greatest impact on mankind, probably since the invention of cooking on fire (Cooley & Tukey, 1964). In 1977, this led to the possibility of converting audio signals into a digital code in a predictable time. Previously, sounds were analogue vibrations of the atmosphere or electromagnetic potentials caused by living beings or loudspeakers. With the FFT, it became possible to describe with digital numbers what the original vibrations were. The consequences were that chips became available that converted audio signals into storable digital code, and later also video signals. The music and entertainment industry was turned upside down by this invention. Today, computers, laptops, telephones and televisions are equipped with this technology and connected to each other via the global Internet.

The FFT did not come about by chance but was the result of years of solid research in mathematics, especially linear algebra. The FFT algorithm selects the Fourier basis functions in the functional vector space that models the corresponding signal and represents the signal by the coordinates of the unit vector in that space. This works in a functional vector space. In general, this is the principle of finding controls for a transfer function to explain an observed effect.

Welcome to the latest new addition to Transfer Functions, Deep Learning 2012!

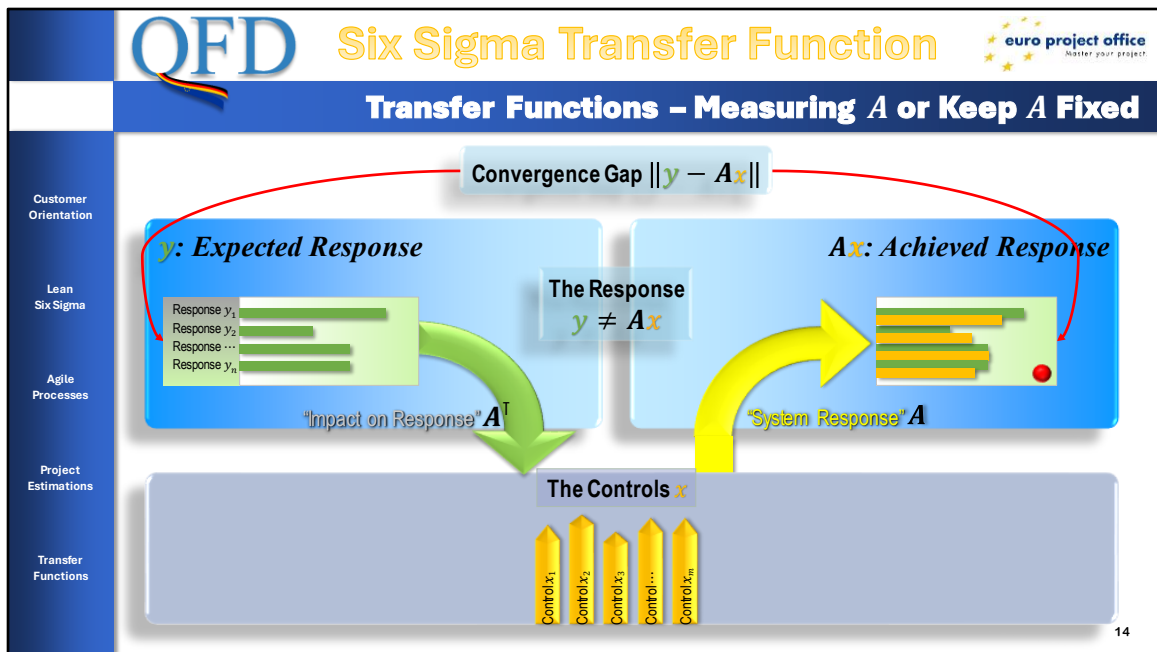


That is the magic formula. Solving the formula for the observable y and the unknown x is what fascinates us.

A is the transfer function that represents the knowledge that we must acquire first. It is not a given functionality, but what we need to learn. Sometimes, in Six Sigma, we can measure (some of the) the elements of the matrix A , sometimes, in QFD, we must guess values based on expert discussions. The controls x are then an optimum solution providing the response y , or something quite close.

Artificial Intelligence is also a solution to this formula. However, the goal is to train the knowledge base A with known facts about y and known responses x . Then, after sufficient training, we can ask the system A by providing an input vector x to get a response y . This requires a much larger matrix A because of the many possibilities that different input vectors x can generate.

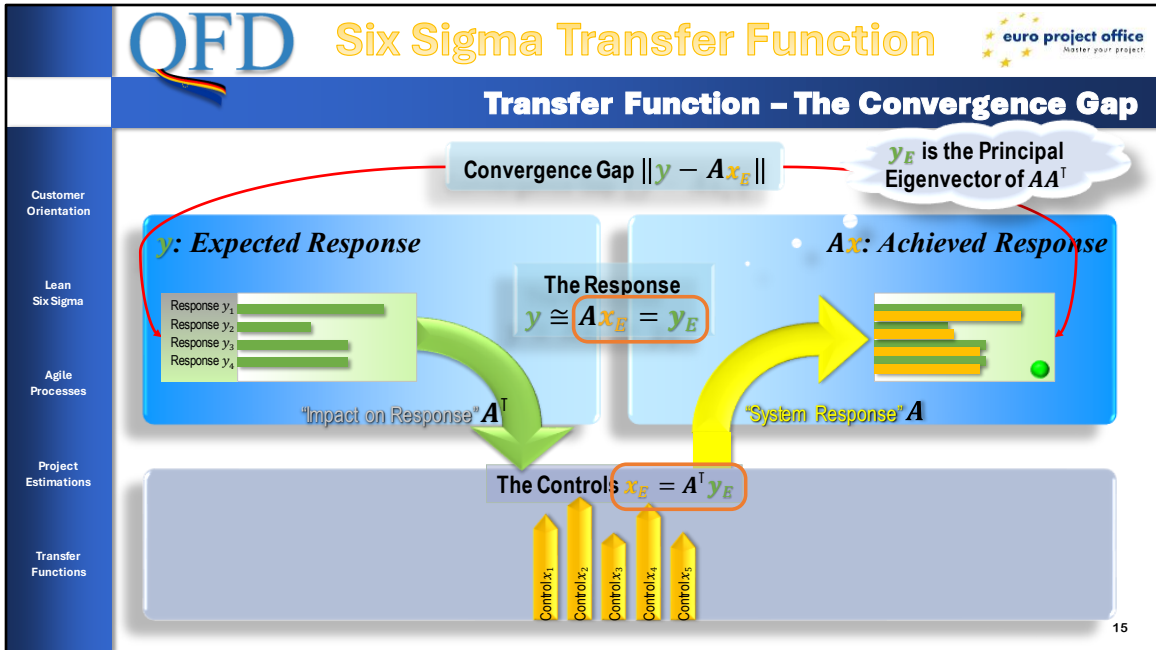
In AI, we must deal with neural networks that can be represented as sparse matrices of huge size (ChatGPT has some $40'000 \times 70'000$ neuronal cells). In good old QFD we probably can manage 12×20 .



In AI, the matrices are no longer 3×4 , but $30'000 \times 40'000$, for a Large Language Model for instance. The principle is still the same:

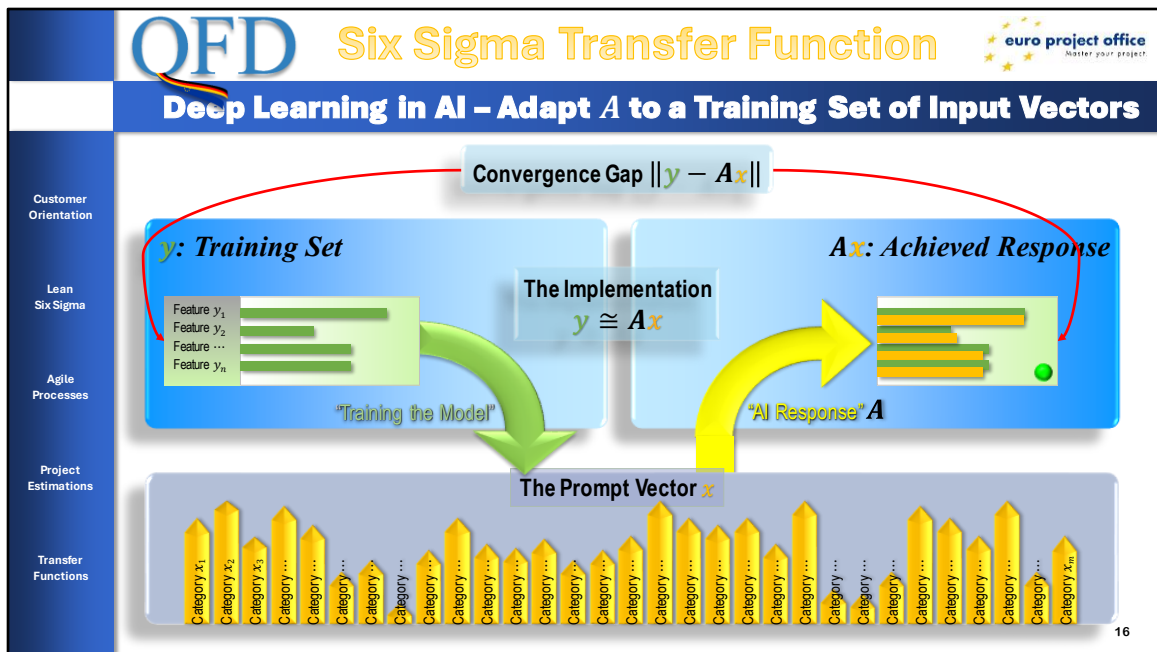
- Count frequencies of characteristics of samples provided;
- Link to objects recognizable by a Neural Net, i.e., some very large matrix;
- Apply Neural Net to queries.

If the result is unsatisfactory, improve the Neural Net by adjusting the weights of its neurons.



Now, applying transfer functions for new product development is straightforward. The intended response define the goals of a product: the “What”. The controls are whatever makes the product work as intended by defining the “How”.

The difference between the expected response y , and the achieved response Ax , is called the *Convergence Gap*. It is the Euclidian length of the vector difference between the achieved system response Ax and the expected goal response y .



The principle of **Deep Learning** is similar between humans and machines – it means that setting a transfer function A which, given an input vector x , produces a response Ax that is sufficiently close to the correct answer; correct in the sense that it matches the features of the training set.

For an **Artificial Neural Networks** (ANN), which here corresponds to the neural network A , the weights of the nodes is adjusted so that the response vector Ax matches the training features y as best as possible. The difference between y and Ax is called **Convergence Gap**.

This difference is calculated by the Gauss' method of the least squares.

QFD

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Agenda

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QFD as Algebra of Combinators

AI as Algebra of Combinators

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Conclusions

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QFD



Counting Frequencies

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- **Large Language Models (LLM)**
 - ➔ Generative Pretrained Translator
 - ➔ Pretrained by counting words and their sequence
 - It understand nothing
 - ➔ 80° Temperature
 - Means that it selects randomly among the 20% best matches
 - Otherwise, LLM become boring
- LLMs can be used to provide a flawless, elegant English
 - ➔ And a few other languages as well, including Kölsch and even Schwyzertüsch
 - ➔ "Daach zosamme!" or «Guete Morge zäme»




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The basics of AI is the same as with QFD: we count frequencies to get the weight of some component.

LLM counted words in many different languages, mostly from the web. With that count, it can calculate what words belong together, their context, and how often word 1 is followed by word 2, and so one. This yields stylish but meaningless phrases.

Such a probability counts is called a **Large Language Model** (LLM).

QFD



Tokens

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- An LLM does not use English words but tokens
 - ➔ Tokens modify a linguistic structure just like endings like “-ing” do
 - ➔ It is the basis for the Translator

- Tokens are more easily to count and to cluster into nearby embeddings
 - ➔ Embeddings are similar objects
 - E.g., dogs and cats are common pets, whereas crocodiles are not
 - All embeddings are enumerated
 - Tokens have a distance between them

- As results we must solve very large matrices
 - ➔ Like good old Quality Function Deployment (QFD)
 - ➔ Although much, much larger



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an LLM uses tokens, not English words. For translations, this makes things considerably easier.

On the other hand, to represent a simple but general English sentence, you need up to 40'000 tokens. These tokens must be lined up with their context, embedded with similar objects, and processed accordingly.

Since all tokens are enumerated, all context become vectors, and we end up in vector space with 40'000 dimensions. To work with vectors, you need linear matrices, and they get quite big, with millions of cells.

These are sparse matrices, because not all objects in the real world, and not all words in natural language, interact together.

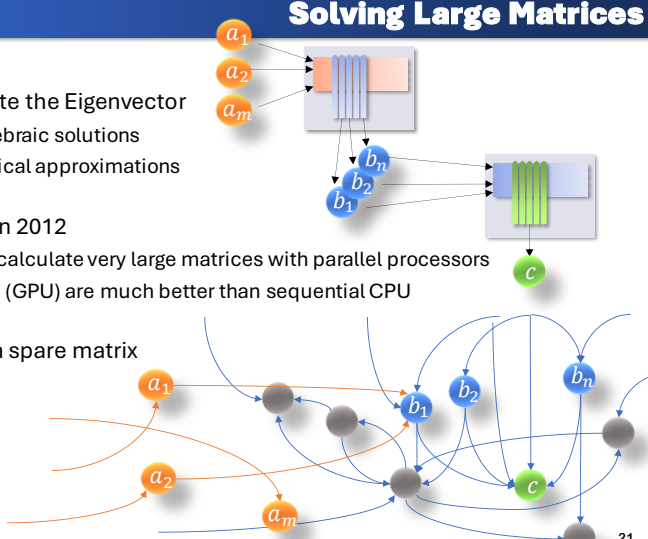
QFD



Solving Large Matrices

- There is no hope to calculate the Eigenvector
 - ➔ There doesn't exist an algebraic solutions
 - ➔ All Eigenvalues are numerical approximations
- The big breakthrough was in 2012
 - ➔ It was understood how to calculate very large matrices with parallel processors
 - ➔ Graphical Processor Units (GPU) are much better than sequential CPU
- A typical large AI matrix is a spare matrix
 - ➔ Most cells remain empty
 - ➔ This is why they are called

Neural Nets




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Until 2012, it was quite unclear how to calculate such large mathematical objects. While Neural Nets were known since at least 80 years, to work with them and let them produce reasonable results, was impossible.

Engeler and Scott found that Neural Nets yielded a **Graph Model of Combinatory Logic**, and this was interesting because combinatory logic provided a foundation for human knowledge that didn't use quantifiers. Thus, it was possible to do sensible things without the need to phrase sentences such as "For all X, it holds some statement F(X)". We know since Russel (Antinomy, 1902) that such phrases always ran us into difficulties, contradictions in logic and mathematics, and deadly prejudices in society.

QFD

$$M \bullet N = \{b | \exists a_k \rightarrow b \in M, a_k \subset N\}$$



The Graph Model of Combinatory Logic

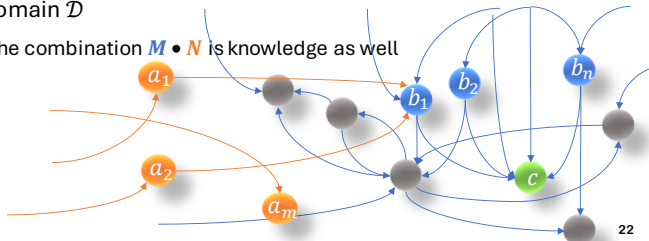
Selection of Observations


$x_j \rightarrow y$

Observed Effect

Grounding Observations

- Algebraic combination of **Observations** and **Concepts** is called **Knowledge** about some Domain \mathcal{D}
- ➔ If M and N is knowledge, the combination $M \bullet N$ is knowledge as well
- ➔ $M = ((a_m \rightarrow b)_n \rightarrow c)_j$
- ➔ $N = (a_m \rightarrow b)_n$
- $M \bullet N = c_j$





New knowledge, represented by arrow terms, can be generated by combining existing knowledge with new observations. Let $M, N \in \mathcal{G}(\mathcal{L})$. Then application of M to N is defined by

$$M \bullet N = \{b | \exists a_i \rightarrow b \in M, a_i \subset N\}$$

In case of M as new observations, and N as existing knowledge, this represents the selection operation that chooses those observations $(b_i \rightarrow a)_j$ from knowledge set M that are extend current knowledge N . The definition applies to all higher-level $\mathcal{G}(\mathcal{L})$ terms.

Maybe a little bit complicated, but effective. The approach originates from intuitionistic and constructivist logic, avoiding the famous undecidability trap.


The Graph Model of Combinatory Logic was identified by Dana Scott, an American logician who is the emeritus Professor of Computer Science, Philosophy, and Mathematical Logic at Carnegie Mellon University, and Erwin Engeler, retired Professor ETHZ, in the 1970s.

In 2019, Engeler described in his seminal paper “Neural algebra on ‘how does the brain think?’”, Theoretical Computer Science, 777, 296-307. how to model biological neuronal behavior with the Graph Theory.

“Grounding observations” means that AI classes of objects are linked to objects in the real world (Zhong, V. et al., 2022. Improving Policy Learning via Language Dynamics Distillation, Cornell University: arXiv:2210.00066v1 [cs.LG]).

QFD

$$M \bullet N = \{b | \exists a_k \rightarrow b \in M, a_k \subset N\}$$



What is Intelligent AI?

Selection of Observations

$x_j \rightarrow y$

Observed Effect


Grounding Observations

- Intelligence means two different skills
 - ➔ Collecting data (CIA, FBI, ...)
 - ➔ Understanding data (**νοῦσ**)
 - ➔ **Intelligent Systems** are smart

- An LLM is intelligent in the first sense, but not smart
 - ➔ It finds answers by statistical fit from the data it collected
 - ➔ It has no idea why this fits

- Knowledge means
 - ➔ Know the data
 - ➔ Know the rules
 - ➔ Work smart

- The **Graph Model of Combinatory Logic**
 - ➔ Selecting relevant instances from the world that it represents (grounding)
 - ➔ It is **Turing complete**:
 - That means you can write rules and full algorithmic programs in the same model



Erwin Engeler
 Professor emeritus of Logic and Computer Science,
 Mathematics Department,
 ETH, Zurich

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The problem with AI is, AI is not intelligent. At least not intelligent in sense of smart. Smart Things in IoT are often called Intelligent Systems, but today less popular than all the AI engines.

Νοῦσ is what Homer attributed to the android robots (read as female by Homer) of Hephaistos: they were not only able to understand what their master god was saying, but also what he meant. These androids were able to make a new suit of armor for Achilles after his friend Patroclus lost it to Hector.

Engeler and Scott found around 1980 that there is a graph model of combinatory logic that is Turing-complete and thus can be said representing knowledge in an algebraic way. These arrow terms represent edges in a neural network, between many observations x_j and some observed effect y .

The graphs represent neural networks and therefore the model has some impact on modern AI.

QFD



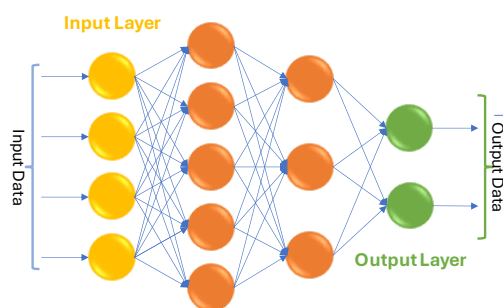
Three Types of Knowledge Graphs

Customer Orientation
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1

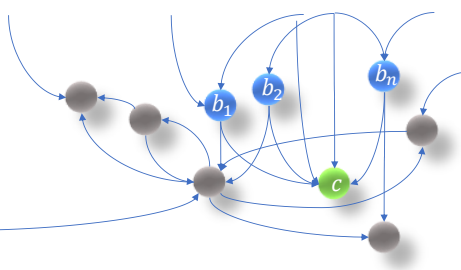
- Recognizing Objects
- ➔ For instance, visual recognition

Input Layer



Hidden Layers

Output Layer




- $c \in \mathcal{D}$
- ➔ Graph evaluates to domain element
- ➔ Visual object recognition
- ➔ LLM language recognition

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There are three different types of knowledge graphs.

The first type ① is about graphs that remember objects, visual or textual. The neural network created by this graph can be used to recognize objects. This means a graph evaluates from some given input and finds out what this object is all about: name, properties, use, description, and whatever can statistically be captured about such an object.

QFD

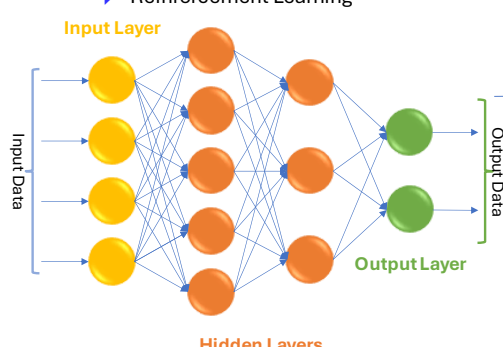


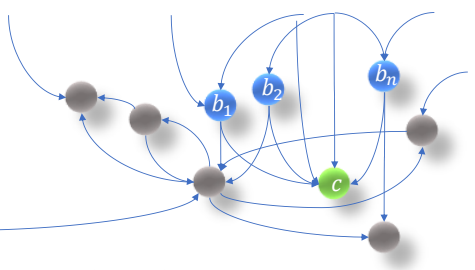
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- Recognizing Rules
 - Looking at behavior
 - Reinforcement Learning






- $c \in (a \rightarrow b_j)_k$
 - Rules recognition
 - Behavior learning

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Another application for neural networks is remembering rules. Rules are also arrow terms but with a temporal meaning of the arrow. A type 2 knowledge graph tries to remember rules, for instance for learning behavior or preferences of a skilled user.

QFD



Three Types of Knowledge Graphs

Customer Orientation

 Lean Six Sigma


 Agile Processes

 Project Estimations


 Transfer Functions

3

- Closed Loop Graphs
 - Called Lambda Concepts
 - Algorithmic behavior
 - Traditional Programs
 - **Logical Derivation**



- Substitution of arrow terms
 - $I = a_1 \rightarrow a$
 - $K = a_1 \rightarrow \emptyset \rightarrow a$
 - $S = (a_i \rightarrow (b_j \rightarrow c))_1 \rightarrow (d_k \rightarrow b)_i$
 $\rightarrow (a_i + b_{j,i} \rightarrow c)$
 - $\lambda f. Kf = S\lambda f. K\lambda f. f = S(KK)I$




26

Type 3 knowledge graphs are quite different. As graphs, they are closed loop. Moreover, since knowledge can be empty, some of these graphs are rather difficult to visualize. Or how would you display the combinator K ?

Type 3 knowledge graphs are well-known as algorithmic programs. Although their name “Lambda-Concept” points at something very theoretical, they represent the Python-programs that actually run all these AI-Engines such as Agents, Bots, Categorizer, etc. that appeared in the last years, since the inception of Large Language Models (LLM).

QFD



Three Types of Knowledge

Customer Orientation

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 Agile Processes

 Project Estimations

 Transfer Functions

● Three Types of Knowledge

1 → What objects should it recognize?

- The underlying domain objects
- Perceptrons that recognize them
- Many solutions for the same object

2 → What concepts should it learn?

- Some concepts are easier to learn than being programmed
- Continuously adapting to user's behavior and preferences

3 → Which concepts are compulsory?

- Deterministic behavior
- Structural knowledge
- Algorithmic programs

● Technical Solutions

→ **Training Models**

- Typical samples from a typical world
- Deep Learning, continuous updates
- Neural networks

→ **Reinforcement Learning Concepts**

- Learning to perform actions that are typical for the domain they are built for
- Continuously adapting by collecting and evaluating experiences

→ **Lambda Concepts**

- Reacting on specific objects & scenarios
- Predefining behavior
- Compulsory decisions

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We therefore need to specify not only the objects that our intelligent systems must be able to recognize, but also the compulsory concepts, and how it should learn new concepts.


We classify thus requirements in three categories that correspond to three different technical solutions. Compulsory concepts can be identified with User Stories for traditional programs (type **3**) with deterministic functionality, while type **1** and type **2** requirements have a lower reliability because they might reflect an LLM hallucination.

Two kinds of knowledge are observational and evaluate to recognized objects or concepts from the base domain; they can be learned by perceptrons; one kind of knowledge is processual and makes it possible to program behavior and object recognition.

There are always a multitude of solutions. Knowledge is not reducible to some normal form; neither Combinatory Logic nor Requirements.

This is a consequence of Gödel's undecidability theorem.





Three Types of Tests

Customer Orientation

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 Agile Processes

 Project Estimations

 Transfer Functions

● Three Types of Knowledge

1 → What objects should it recognize?

- The underlying domain objects
- Perceptrons that recognize them
- Many solutions for the same object

2 → What concepts should it learn?

- Some concepts are easier to learn than being programmed
- Continuously adapting to user's behavior and preferences

3 → Which concepts are compulsory?

- Deterministic behavior
- Structural knowledge
- Algorithmic programs


● A Test is passed, when

- The AI Agent recognizes the object with expected reliability
 - The individual test case is not predictable
 - The knowledge is of limited reliability
- The AI Agent recognizes the concept
 - The individual test case is not predictable
 - The knowledge is of limited reliability
 - Design of AI Agent must include corrective measure in case the response is wrong
- Responses are correct
 - The AI Agent uses knowledge that is 100% reliable – usually written in Python
 - Testable like any traditional program

Tests are passed depending on the type of knowledge. In case of the two that are observational and evaluate to recognized objects from the base domain or observed rules about the domain, Tests have a statistical variability. Test Cases can be true, false true, false wrong, or wrong.

Only the tests for the closed loop type of knowledge have a well-defined result. This is how we test AI Agents that are relevant to business, or security, or safety.

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Explainable AI (XAI)

Customer Orientation

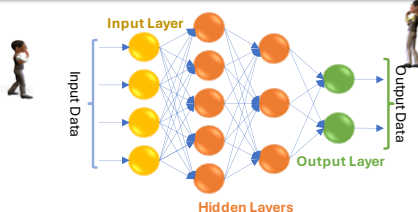
 Lean Six Sigma

 Agile Processes

 Project Estimations

 Transfer Functions

- A big problem for AI is that nobody knows what happens in hidden layers
- It is unlikely that hidden layers implement the most straightforward arrow schemes
 - ➔ In contrary, combinatory logic has no normal form
 - ➔ There exist many ways to find a valuable result, even for the same result
- Regulators try to impose rules for training sets
 - ➔ It is very difficult to assess quality of a training set, because knowledge is always limited
- Current explainability techniques
 - ➔ SHAP (SHapley Additive exPlanations) is a game-theoretic approach
 - ➔ LIME (Local interpretable model-agnostic explanations) is a method that fits a surrogate glass-box model around the decision space of any black-box model's prediction
 - ➔ A lot more, all based on statistical correlations, not on reasoning




29

The problem with explainable AI is certainly that the hidden layers in a perceptron remain hidden. They are not labeled as with comprehensive QFD.

Nevertheless, there exist many explainability techniques. However, all have the problem that they use statistical correlations as a basis for reasoning. That cannot go well because of Gödel's undecidability theorem. But it's probably better than nothing.

These tools shall create trust and block further investigations.

QFD



Intelligent Systems are Based on Controlling Combinators

Customer Orientation

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 Agile Processes

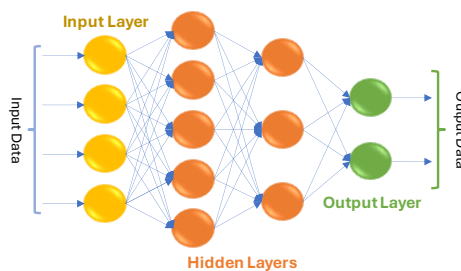
 Project Estimations

 Transfer Functions

- **Controlling Combinators** C do loop and augment knowledge X under control
 - ➔ Controlling Combinators are of type ③
 - ➔ Focusing $X_{i+1} = C \cdot X_i, i \in \mathbb{N}$
 - ➔ Control Sequence $X_0 \subseteq X_1 \subseteq X_2 \subseteq \dots$
 - ➔ The amount of available knowledge is measured as **Reliability**
 - ➔ Stop looping when approximation to correct response is good enough

- Neural Networks in the brain do loop!
 - ➔ Controlling Combinators keep looping programs under control

- Deep Learning by multi-layered perceptrons (MLP) is ordered
 - ➔ No loops from input layer to output layer




30

However, there are open questions. Humans must likely use neural networks with feedback loops. AI does not.

What could happen if AI learns how to use feedback loops? **Controlling Combinators** (Engeler 2019, “How does the brain think”) are crucial for further developing artificial intelligence and better approximate human intellectual capabilities.

QFD



Intelligent Systems Consisting of Many AI Engines

Customer Orientation

 Lean Six Sigma

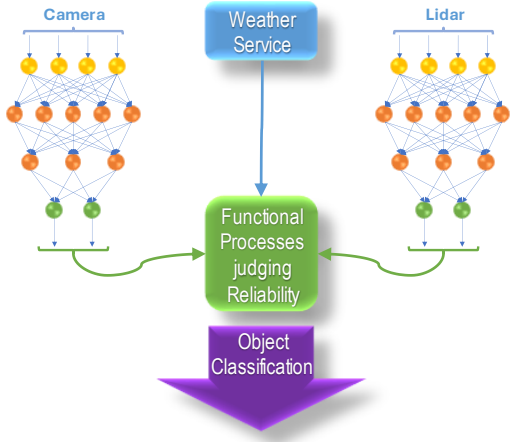
 Agile Processes

 Project Estimations

 Transfer Functions

- Assume reliability can be measured
 - ➔ You can compare reliability of two AI engines, e.g., camera and Lidar
 - ➔ The judge about which reliability is higher
 - That might depend on external factors such as weather condition or lighting
 - ➔ Then decide according to the best prediction

- Intelligent systems arise from cooperation between AI and functional programming



31

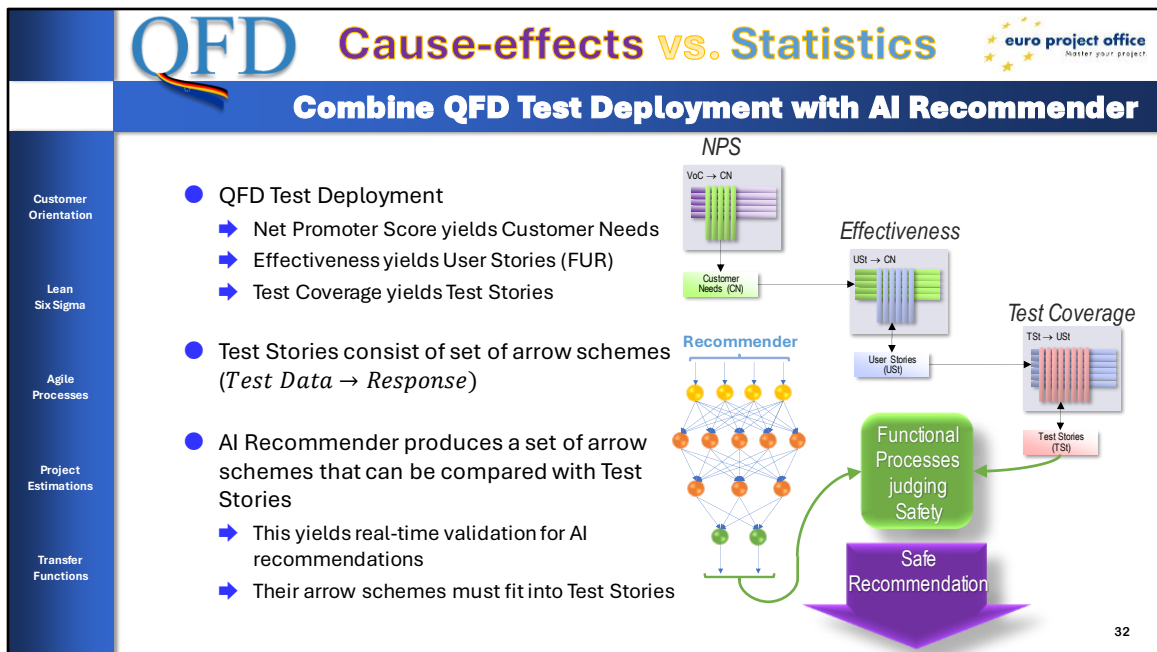
It is also possible to add more than one AI engine to an intelligent system, compare results and go forward with the most reliable one. Insufficient training, biases, and hallucinations therefore would become detectable.

This slide shows an example of an intelligent system design that relies on two separate visual recognition engines analyzing the same scenario, one through a camera and the other through a Lidar.

Such an architecture requires that the reliability of each artificial intelligence engine be known, under certain conditions, such as weather. In this way, the intelligent system can explain why it selected one or the other response.

Obviously, if both AI-engines produce an identical response, this increases overall reliability of the response of the intelligent system quite a bit.

The graph model delivers the metrics for defining controlling combinators by inclusion, and it also allows to combine knowledge and thus reliability correctly.

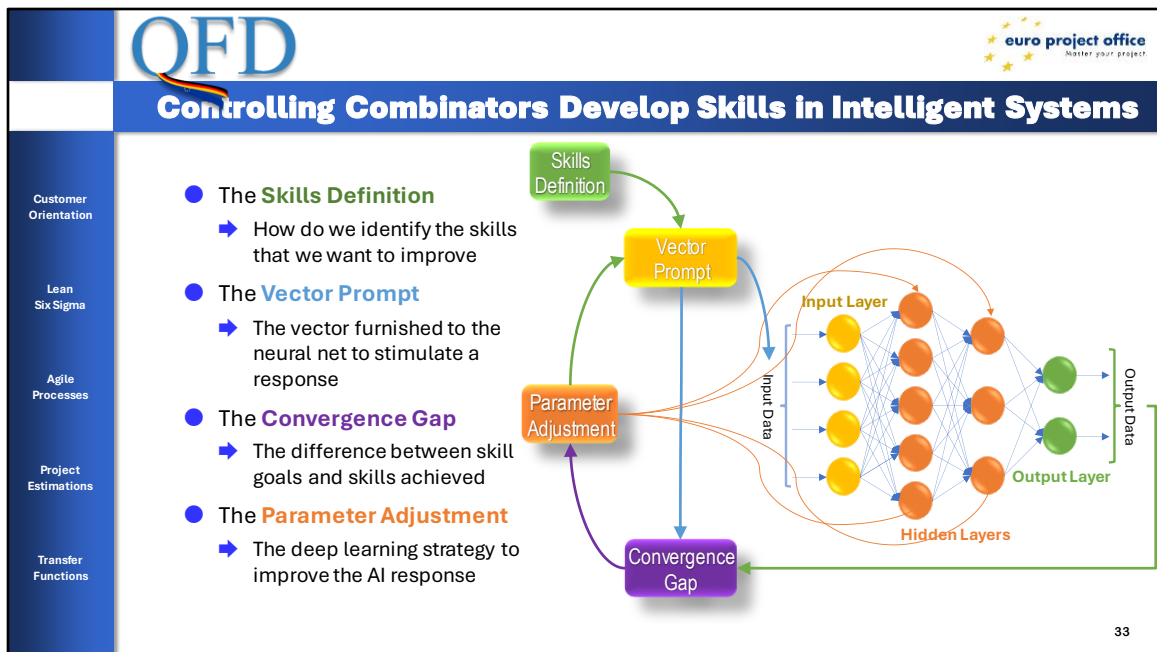


This is yet future work, just an idea, not yet thought through.

Arrow schemes also work well as representation for test stories.

The QFD Test Deployment is an upfront investment that defines the range of acceptable responses. Thus, all you must do is use the same tokens for QFD and for AI and compare them.

More sophisticated combinations are also possible, for instance, combining the Recommender with a Controlling Combinator for continuous learning.



These functional processes depend on two parameters: the skills definition and the feedback from some external authority. This includes the convergence gap definition that must be provided externally from some empirical source. The convergence gap is the gap between skills and external expectations.


Then the intelligent system can do the fine-tuning autonomously by gaining control over certain capabilities. It needs feedback from attractors in the external world, and these attractors are implemented by functional processes that compute the convergence gap against some external reference and feed back the result to the AI engine for improvement.

Thus, intelligent systems are a joint venture between AI engines and traditional functional processes.

Obviously, the **Convergence Gap** creates the problem how to calculate it.

.

QFD



The Cause-Effect Concept Generator (CECG)

Customer Orientation


 Lean Six Sigma

 Agile Processes

 Project Estimations

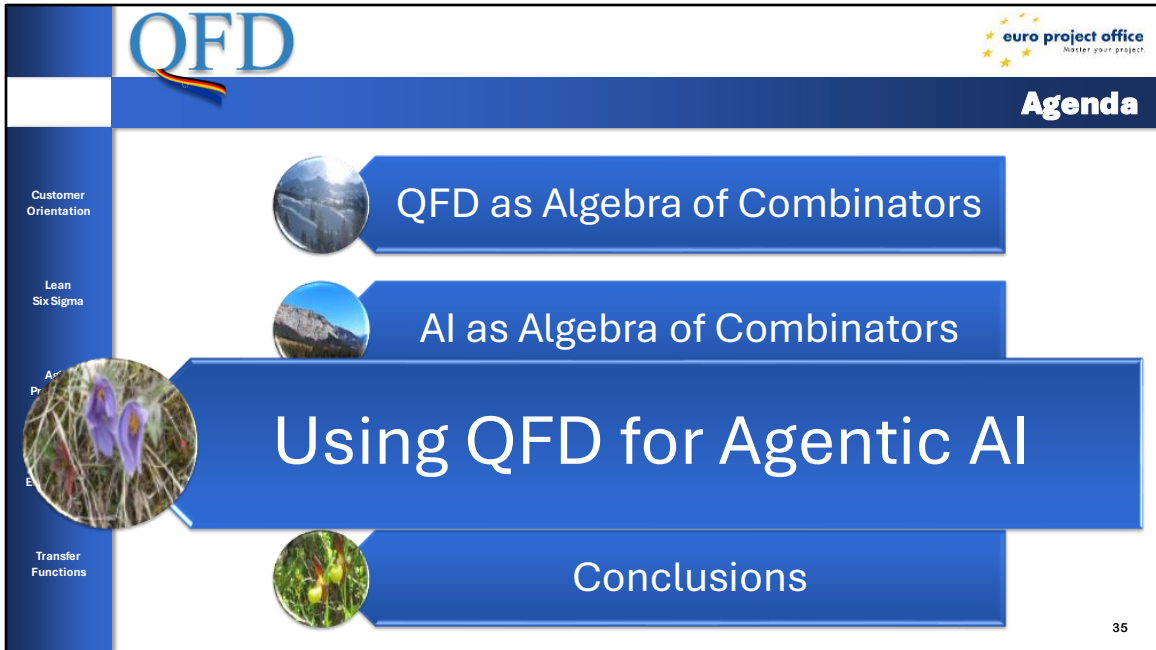
 Transfer Functions

- An **Intelligent System** is a hybrid system between Symbolic AI and LLMs that checks responses with a **Cause-Effect Concept Generator (CECG)**
 - ➔ A CECG generates rules derived from some rule set, using the same tokens as the LLM
 - ➔ Because tokens have a distance, building a convergence gap calculator is relatively easy
 - ➔ The CECG uses mathematical logic to derive valid combination of rules
- 15 years ago, the world was full of IoT Smart Systems, also called Intelligent Systems
 - ➔ However, they used no AI Engines
 - ➔ All was algorithmic
 - ➔ Type ③ requirements
- An LLM is not smart
 - ➔ A CECG can be smart
 - ➔ It's classical, symbolic AI
 - ➔ With smart search



15 years ago, the world was full of IoT Smart Systems, also called Intelligent Systems. This seems forgotten, nowadays where there is AI. However, smart systems followed predominantly type ③ requirements, i.e., they were algorithmic. Surprisingly, you cannot solve all problems with deterministic algorithmic solutions (because of Gödel's Incompleteness Theorem).


Nowadays, we use CECGs to keep LLMs under control.



The slide features a blue header with the 'QFD' logo on the left and the 'euro project office' logo on the right. Below the header is a dark blue bar with the word 'Agenda' in white. On the left side, there is a vertical blue bar containing the text 'Customer Orientation', 'Lean Six Sigma', and 'Transfer Functions'. The main content area consists of four blue horizontal bars, each with a circular image on the left and text on the right. The bars are: 1. 'QFD as Algebra of Combinators' with a landscape image; 2. 'AI as Algebra of Combinators' with a mountain image; 3. 'Using QFD for Agentic AI' with a purple flower image; 4. 'Conclusions' with a green plant image. The number '35' is in the bottom right corner.

- QFD as Algebra of Combinators
- AI as Algebra of Combinators
- Using QFD for Agentic AI
- Conclusions

QFD



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Modeling Functionalities According to ISO 19761 (COSMIC)

Customer Orientation

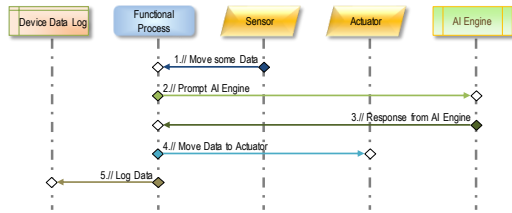
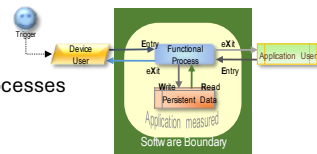
 Lean Six Sigma


 Agile Processes

 Project Estimations

 Transfer Functions

- **Data Movements** move **Data Groups**
 - ➔ **Data Groups** categorize what kinds of data is moved between objects
 - ➔ **Data Groups** are relevant for security aspects, such as **Privacy** and **Safety**
 - ➔ **Data Groups** transport **Knowledge**
- Data Movements always involve a **Functional Process**
 - ➔ Either **Entry & eXit**, or **Read & Write**
 - ➔ Functional Processes communicate with other Functional Processes either via Devices, or Persistent Data
- Data Groups containing knowledge have a certain **Reliability**




COSMIC 36

The ISO/IEC 19761 international standard exists since more than 20 years and defines a way of modeling the functionality of software. Neither quality aspects are considered, nor implementation details. The model is equally valid for own code, for services originating from elsewhere (e.g., the cloud) including microservices, and for the expected behavior of intelligent devices or services. It measures functionality by counting **Data Movements** (Entry & eXit, or Read & Write), that move **Data Groups** between **Objects of Interest**. Data groups are always moved from or to a **Functional Process**; objects performing tasks according to **Functional User Requirements** (User Story).

Functionalities are expressed as User Stories in the Agile context. According to ISO 14143, functional requirements must meet a defined level of granularity. **User Stories** name the device user, the requestor, and describe what a functional process shall do, specifying data stores, devices, and other applications needed.

Creating a **Data Movement Map** from a set of user stories is an easy way of modeling functionalities with defined granularity.

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In AI, Data Groups become Knowledge with Varying Reliability

Customer Orientation

 Lean Six Sigma

 Agile Processes

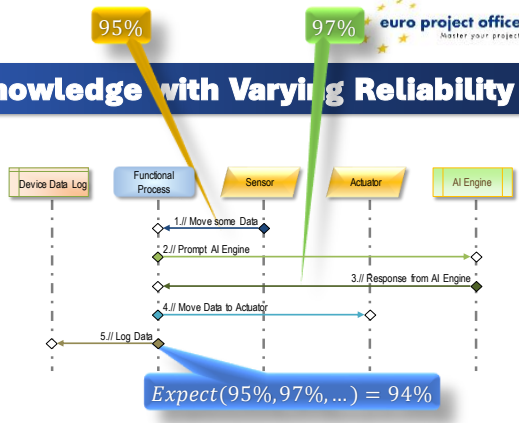
 Project Estimations

 Transfer Functions

- **Reliability** of Data Groups depends on the Objects of Interest
 - ➔ Devices
 - Data comes with a reliability ratio
 - ➔ Other Applications
 - An AI app comes with a reliability ratio
 - ➔ Persistent Data
 - Might contain data with a reliability ratio

- **Reliability** of Data Groups combines on Functional Processes
 - ➔ Combination calculates statistical expectation of reliability originating from all input data groups
 - ➔ Functional Processes yield data groups with combined reliability

- Programmers of AI should take care of reliability of the data groups moved




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Reliability ratios can be assigned to *Objects of Interest* – Devices, and Other Application (AI), reflecting the degree of trustworthiness, of data originating from them. Persistent Data objects, that might contain untrusted data resulting from some knowledge-dependent action, or from a sensor, has also a limited reliability ratio, but the persistent data object does not change reliability. These objects of interest dynamically produce data groups with varying, limited reliability. Although reliability is measured commonly by a percentage number, it is a standard deviation, not a linear reliability average.

The Functional Processes combine these reliabilities, by combining insecurities inherent with knowledge-based actions. Thus, in our sample, the minimum reliability of data groups originating from the (blue) functional process is the combination of the reliability of all incoming data.

If data is persistently stored, it retains its reliability.

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A Simple AI Agent for Implementing Business Processes

Customer Orientation

 Lean Six Sigma


 Agile Processes

 Project Estimations

 Transfer Functions

- Our Organization needs an AI Agent that quotes customers individually based on
 - ➔ Business Rules
 - For Terms & Condition
 - Discounts
 - ➔ Price Book

- Customer Needs
 - ➔ By AHP
 - ➔ Integrating stakeholders
 - End Customers
 - Management
 - Compliance

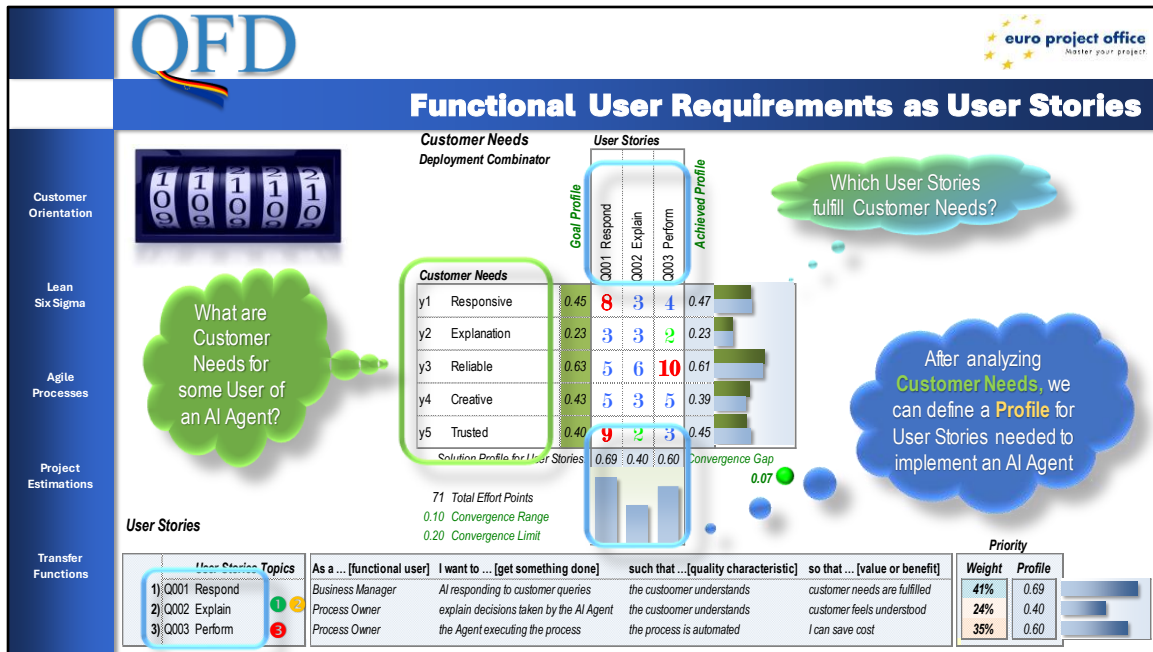


Customer Needs	y1 Responsive	y2 Explanation	y3 Reliable	y4 Creative	y5 Trusted	Weight	Ranking	Profile
y1 Responsive	1	3	1/3	1/6	6	21%	2	0.45
y2 Explanation	1/3	1	1/3	1/3	3	11%	5	0.23
y3 Reliable	3	3	1	6	1	29%	1	0.63
y4 Creative	6	3	1/6	1	1/6	20%	3	0.43
y5 Trusted	1/6	1/3	1	6	1	19%	4	0.40

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Assume, we want an AI Agent that responsibly and sustainably quotes customers on our products and services.

We omit all the escalation stuff that is needed in case the AI Agent cannot issue a viable and approvable quote, for the sake of simplicity.




Three User Stories – the first two according to type ① and ②, the third one of type ③.

The three user stories (in blue) implement a system that meets five customer needs (in green). We need a profile for the priorities of those user stories, which are rather epics, due to the granularity chosen for our Café sample.

The numbers in the matrix represent the number of data movements that contribute to fulfilling customer needs in user stories.

Agile Teams have multiple ways of prioritizing user stories with different methods.

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Design of an AI Agent

Customer Orientation

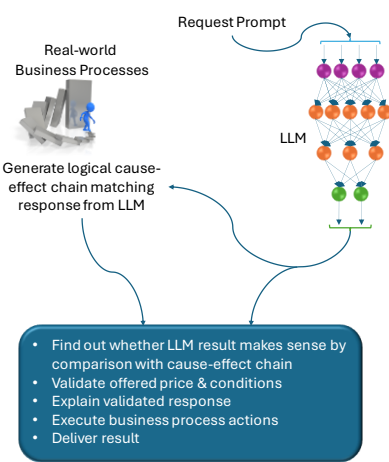
 Lean Six Sigma

 Agile Processes

 Project Estimations

 Transfer Functions

- An **Intelligent System** is a hybrid system between Symbolic AI and LLMs that checks responses with a **Cause-Effect Concept Generator (CECG)**
 - ➔ A CECG generates rules derived from some rule set, using the same tokens as the LLM
- An **AI Agent** is an Intelligent System whose CECG models Business Processes for some organization
- Type 3 requirements for an AI Agent:
 - ➔ All responses must be consistent with business processes
 - ➔ The AI Agent never must hallucinate!



40


A very basic AI Agent is an intelligent system that can respond to user requests for instance with reference to some real-world domain, e.g., an eShop.

The AI Agent must understand what the user needs using basic knowledge involving cause and effect in his domain – for instance, if you want screws, you likely need a screwdriver. Or if you want sound-absorbing ceiling elements, whether you need them fireproof or not.

Moreover, this AI Agent never must quote wrong prices!

That we must test; otherwise, we run into liability risks.

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Design of an AI Agent

Customer Orientation

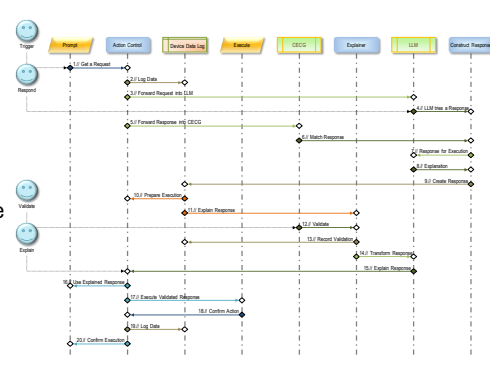
 Lean Six Sigma

 Agile Processes

 Project Estimations

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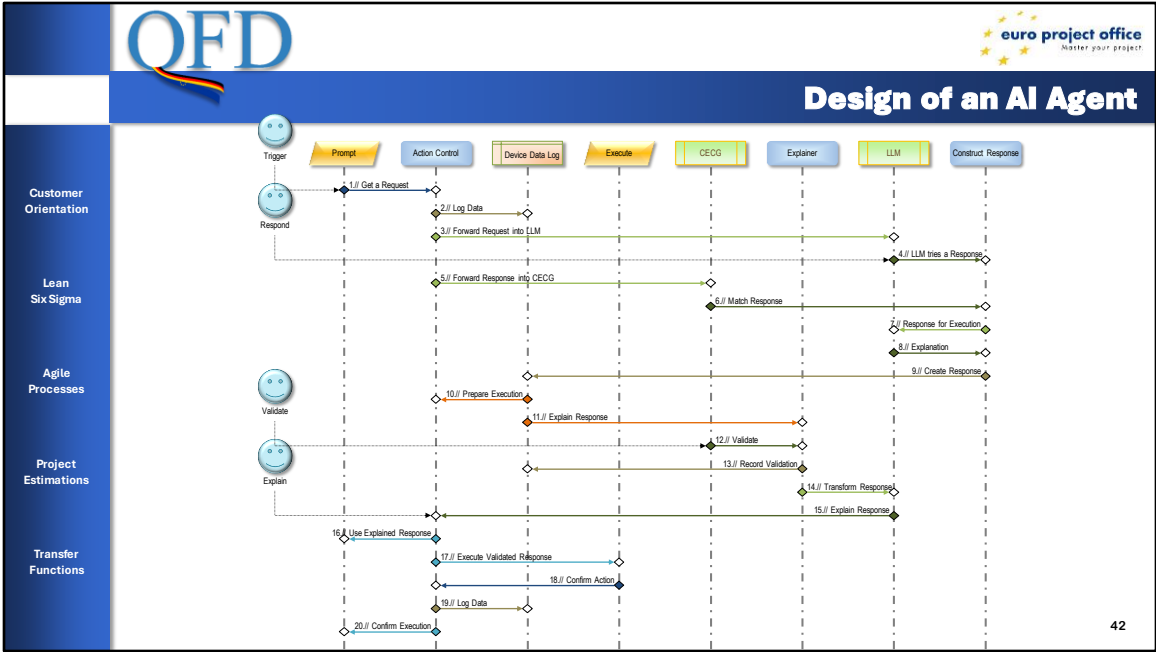


41

An AI Agent is best designed by modelling data movements according to ISO 19761 COSMIC because data movements carry the data groups that represent knowledge at different levels of reliability in AI systems.


The above data movement map shows a very simple implementation of the design sketch before. Because only the essential functionality is shown, it fits into this presentation. A real implementation is somewhat more complicated but usually one should set a limit by less than hundred data movements. Thus, a level of granularity is reached that still can be conveyed to humans, e.g., management and peers.

Obviously, what's below the level of granularity chosen, is not seen by testers and thus must remain untested. This allows testing AI despite the very high complexity an AI Agent or AI engine can achieve. This is not a weakness of the approach, in contrary it makes testing feasible even with limited resources. Would we care to test the tensor multiplication algorithm that implement a perceptron?



This is how the data movements look like for such a simple AI Agent. It looks well testable; however, we must consider that responses from an LLM never are the same. They are similar but not identical. These requirements are of type 1 or 2.

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Splitting a Data Movement Map into Independent Test Cases

Customer Orientation

 Lean Six Sigma

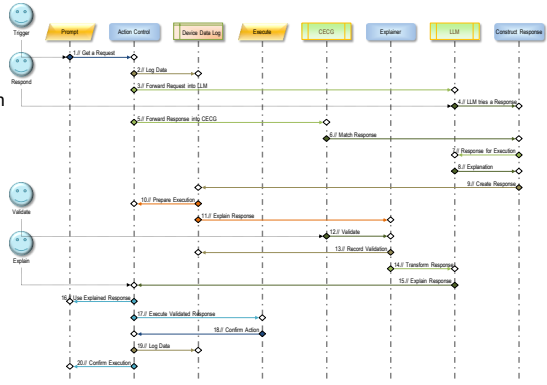
 Agile Processes

 Project Estimations

 Transfer Functions

- Data groups play a major role
 - ➔ Collect the referenced data
 - ➔ Data groups hold test data
 - You might freely choose test data within data group boundaries
 - Thus, tests become executable as soon as the data groups are known for each test case

- For a test case, it is sufficient to consider the data group as test data for each triggered entry data movement
 - ➔ These are the initial graph entries!




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The **Data Movement Model** contains only those elements that are essential for these three requirements for the AI Agent.

The **Objects of Interest** are on a high level, representing a granularity that is sufficient for assessing safety and security.

We expect reliability within some limits – not shown here – but request absolute adherence to Type 3 requirements. Otherwise, the test fails.

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Splitting a Data Movement Map into Independent Test Cases

Customer Orientation


 Lean Six Sigma

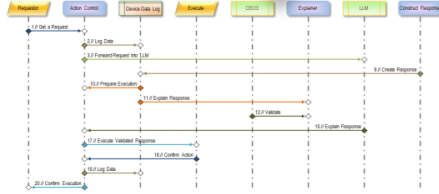
 Agile Processes

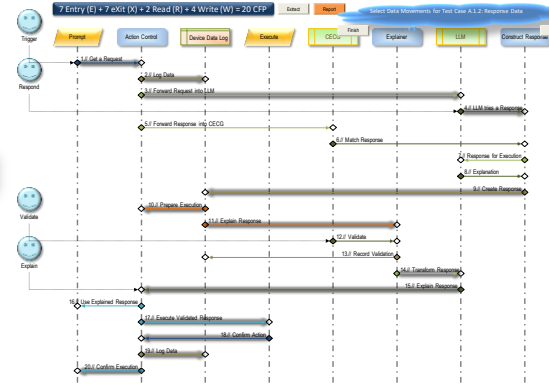
 Project Estimations

 Transfer Functions

- Now click on the data movements that belong to the test case
 - ➔ Test Case must be coherent
 - All data movements must be reachable
 - Data groups might carry a **Reliability**








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A test case consists of a selection of the data movements that are coherent, i.e., reachable. The data groups for our graph representation (arrow terms) are those at the selection of test data and the one data group that holds the test result.

Each of the data movements might hold not only a data group but a reliability as well, when originating from some AI engine such as an LLM or a Visual Recognition System.


QFD

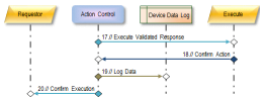


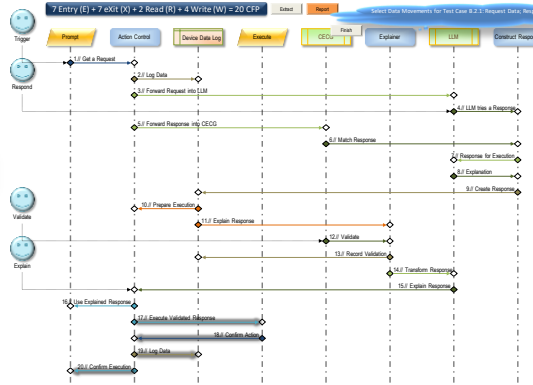
Splitting a Data Movement Map into Independent Test Cases

● Smaller test cases are also possible

➔ Unit tests often consist of one data movement only

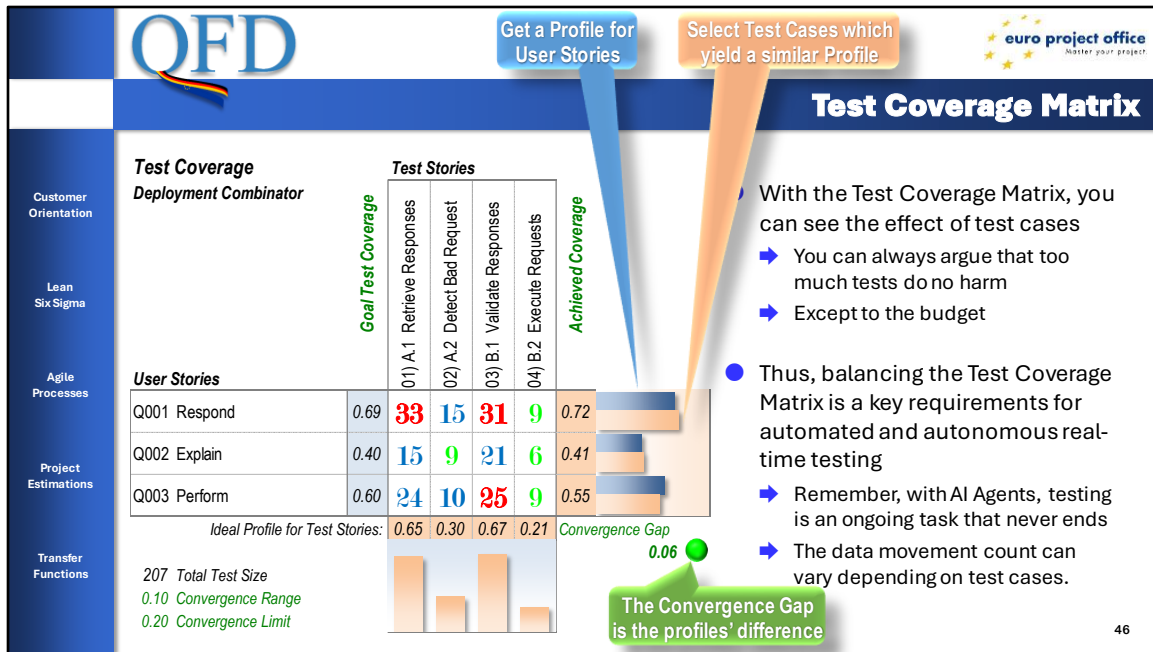






45

Unit test cases typically consist of one data movement only. However, many tests are small and, for execution, require the ability to fill their initial data groups with actual, sample, data.




The Test Cases we organize in Test Stories, bringing together what belongs together, in terms of business requirements (typically **Non-Functional Requirements**, NFR). Then we count the data movements of all test cases that belong to a certain User Story and Test Story. This count yields numbers in the Test Coverage Matrix.

The **Test Coverage Matrix** is very dynamic, as both the user story profile and the test cases in use for some test story can vary.


You can add more test cases, but the test coverage matrix should remain balanced, i.e., the **Convergence Gap** should close.

The (blue) profile for the user stories is well-known to any agile team, or you can look at my presentation last year in Thessaloniki how to assess customer needs and derive a profile for user stories

In any case, the test coverage matrix allows to sieve test cases for relevance to the user stories. The first two user stories are NFR according to type 1 and 2, the third one is a FUR of type 3.





Test Stories
for Capability Testing



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With 14 Test Cases only

	Test Story	Test Cases								Priority		Measured Defect Profile
		Case 1 Test Data	Expected Response	Case 2 Test Data	Expected Response	Case 3 Test Data	Expected Response	Case 4 Test Data	Expected Response	Weight	Profile	
A Prepare	A.1 Retrieve Responses	A.1.1 (Request Date)	Response Date	A.1.2 (Response Date)	Execution Date	A.1.3 (Execution Date Business Process)	Explanation	A.1.4 (Explanation)	Transformed Response	35%	0.65	
	A.2 Detect Bad Request	A.2.1 (Request Date)	No Response	A.2.2 ()	No Execution	A.2.3 ()	Explanation			16%	0.30	
B Response	B.1 Validate Responses	B.1.1 (Bad Request Date Business Processes)	No Execution	B.1.2 (Bad Request Date Business Processes)	No Execution	B.1.3 (No Execution)	Explanation	B.1.4 (Explanation)	Transformed Response	37%	0.67	
	B.2 Execute Requests	B.2.1 (Request Date Response Date)	Execution Date	B.2.2 (Request Date Response Date)	Explanation	B.2.3 (Explanation)	Transformed Response			11%	0.21	

- With 14 Test Cases only, an AI Agent can be tested effectively for compliance to business processes
 - ➔ Or for a price list, or for other real-world constraints
 - ➔ Test Stories A are mainly type ① and ②; responses are type ③
 - ➔ **There is no excuse not to test your AI Agent!**

- But you must do it the right way for AI
 - ➔ This is not an ordinary test
 - ➔ Testing AI is an ongoing process – you're never done with it

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The good news: With 14 test cases only, you can guarantee that your AI Agent is not doing any harm to your organization.

There is no excuse not to test your AI Agent!

The preparatory test stories contains typically type ① and ② requirements, the response test stories are of type ③ .

The bad news: when the AI Agent changes behavior, the test cases vary as well, especially with type ① and ② requirements. Type ③ results must always conform to defined business processes.

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Automated Test Case Execution

Customer Orientation

 Lean Six Sigma

 Agile Processes

 Project Estimations

 Transfer Functions

- Since each data movement moves exactly one data group, once a test case $x_i \rightarrow y$ is known, sample test data from the data groups x_i can be selected
 - ➔ Thus, the test case becomes executable
 - ➔ If the same data group is displayed multiple times, we take them all
 - ➔ The expected result is also displayed as a data movement that moves a specific data group
 - ➔ All what is needed is to specify valid data ranges for these data groups
 - Selecting specific data from a data group, e.g., from a data range, may lead to multiple executions
 - ➔ Any path in the data movement map that leads from the test data to the result can be executed as a test case
 - Thus, a test case does not specify a unique test case execution

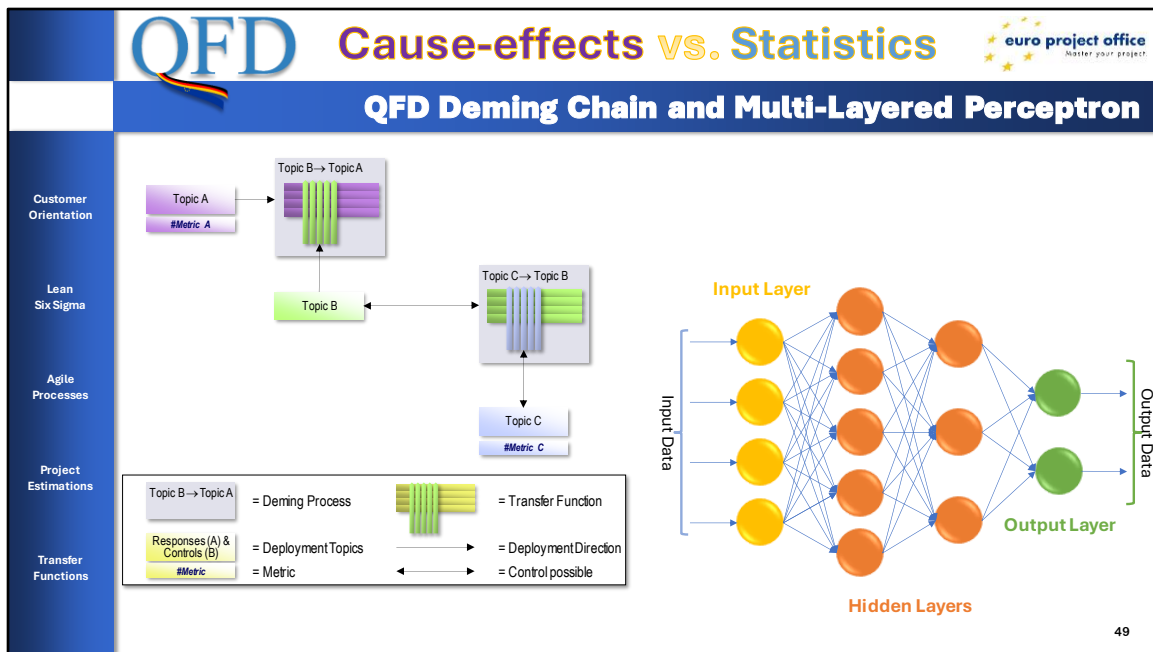
- Not only can test cases be created automatically, thus completing the test coverage matrix, but the execution of test cases no longer requires extra coding
 - ➔ If you have APIs, the approach works also for services where you don't have access to code

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While testing an AI engine is difficult, because it changes behavior, it is always possible to test a functional model.


Nevertheless, it is possible for testing a functional model.

Moreover, if no code is available, e.g., for services, a **Digital Twin** might allow to execute test cases involving such functionalities that depend partly or in full on external services, or that need hardware in the loop. In this case, for the Digital Twins, you must provide code for such external services or hardware.



The big difference between QFD and an *Artificial Neural Network* (ANN), most often designed as a Multi-layered perceptron, is that layers in an ANN are hidden. Otherwise, each layer corresponds to a very large, sparse, matrix. The values in the matrix describe, as in QFD, the strength of coupling the input with the output. If multiple entries in a column exist, they strengthen the response. Most matrix cells remain empty, not stimulating any response.

QFD



QFD Deming Chain and Multi-Layered Perceptron

Customer Orientation

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 Transfer Functions

<ul style="list-style-type: none"> ● In QFD, layers are not hidden <ul style="list-style-type: none"> ➔ Each layer is a matrix in itself ➔ It has a sensible meaning ➔ Matrices are connected by discernible topics ● You can easily explain QFD <ul style="list-style-type: none"> ➔ Although it may look complicated ➔ It's cause-effect relationships ● People won't believe it <ul style="list-style-type: none"> ➔ They rather trust own gut feelings ➔ Otherwise, much more organizations would be prosperous and address customer needs properly 	<ul style="list-style-type: none"> ● In Artificial Neural Networks (ANN) <ul style="list-style-type: none"> ➔ Layers are hidden ➔ They do not refer to some specific topic <ul style="list-style-type: none"> • Exception: Visual Recognition systems ➔ Advantage: Deep Learning is more flexible ● You cannot explain how an ANN works <ul style="list-style-type: none"> ➔ Although it may look simply ➔ It's statistics; it's counting ● People believe (currently) in AI <ul style="list-style-type: none"> ➔ Do they adore authorities? ➔ This might be an evolutionary heritage ➔ Survival of those that followed their leaders
--	---

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This is a comparison between QFD and AI.

In QFD, the flow of inception is easily traceable; however, it is based on measurements or expert evaluations. Both are not easily comprehensible.

AI has no such problems because the layers are hidden, and thus not comprehensible at all.

However, there has been some progress in AI in terms of skills traceability.

QFD



Why isn't QFD Widespread?

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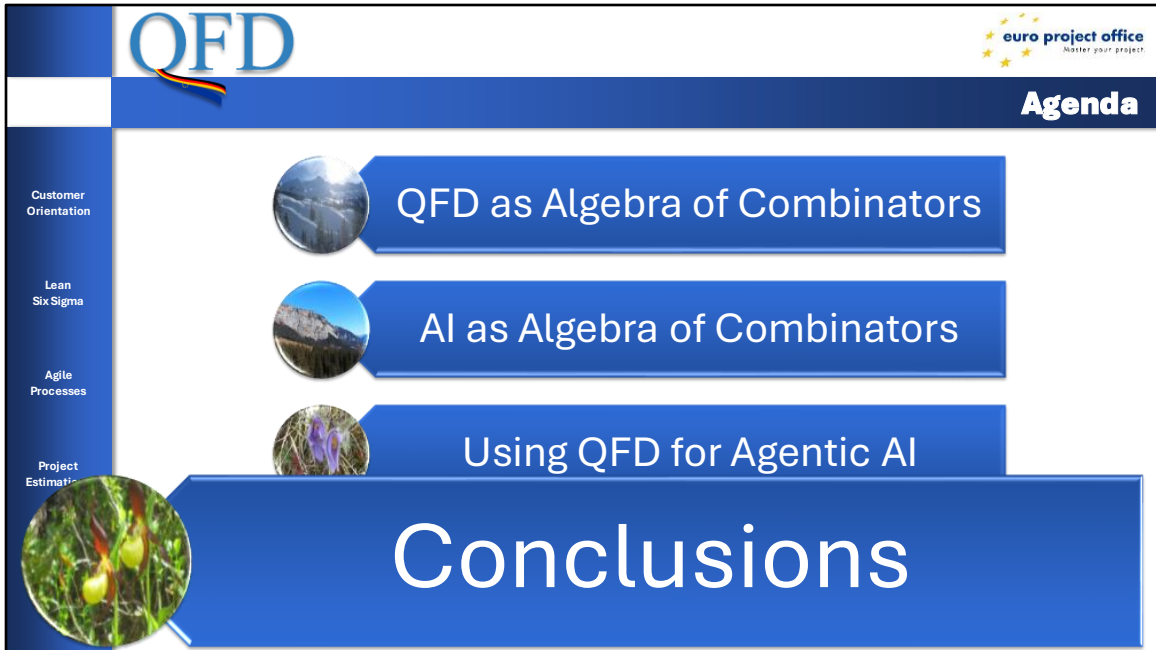
 Transfer Functions

- Just a few personal experiences
 - ➔ Made Swissair best airline again
 - ➔ Proposal Centers with 97% success
 - ➔ Drove a Swiss startup to world leader in personalized communication
 - ➔ QFD in Testing of Complex Systems
- Why are they not here, all of them?
- A possible answer
 - ➔ Being a leader is difficult
 - ➔ You need to claim success for yourself
 - ➔ You cannot afford to be perceived as a follower to some method
 - ➔ Up-front investment aren't agile
- Usually, QFD programs were scrapped after management change
- **AI approaches will run into same problem with leadership & management**
 - ➔ **This happened already four times in history of AI**
 - ➔ **It will happen again**

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Usually, bad leadership successfully kills QFD, and will kill AI, simply because leaders fear the loss of power and influence.

Luckily, some few organizations, typically start-ups, take over and use new methods successfully. It all depends on the stature of leaders.



The slide features a blue header with the 'QFD' logo on the left and the 'euro project office' logo on the right. Below the header is a dark blue bar with the word 'Agenda' in white. On the left side, there is a vertical navigation menu with four items: 'Customer Orientation', 'Lean Six Sigma', 'Agile Processes', and 'Project Estimation'. The main content area contains four blue horizontal bars, each with a circular image on the left and text on the right. The bars are: 1) 'QFD as Algebra of Combinators' with a landscape image; 2) 'AI as Algebra of Combinators' with a mountain image; 3) 'Using QFD for Agentic AI' with a purple flower image; and 4) 'Conclusions' with a large green and yellow vegetable image. The 'Conclusions' bar is the largest and is positioned at the bottom of the main content area.

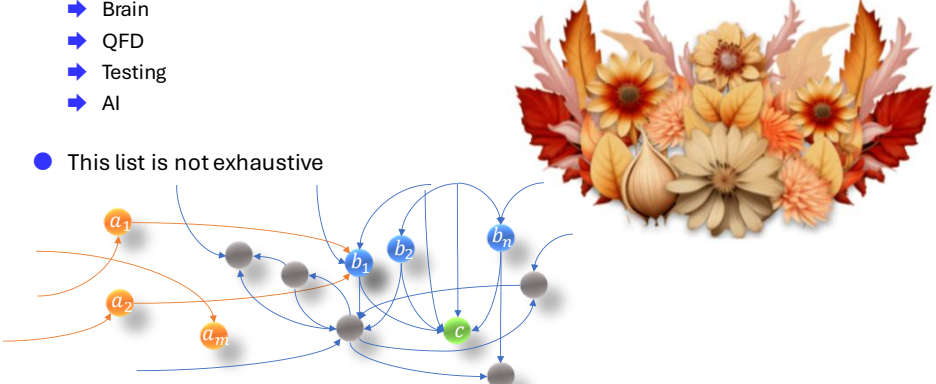
- QFD as Algebra of Combinators
- AI as Algebra of Combinators
- Using QFD for Agentic AI
- Conclusions

QFD

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Conclusion

- There is enough evidence that studying the graph model of combinatory logic yields phantastic insights into
 - ➔ Brain
 - ➔ QFD
 - ➔ Testing
 - ➔ AI
- This list is not exhaustive



Customer Orientation

Lean Six Sigma

Agile Processes

Project Estimations


Transfer Functions

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The graph model of combinatory logic is filling the gap between logic and nature. It is highly recursive and applicable to any kind of knowledge – QFD, Testing, AI, ...

QFD

Cause-effects vs. Statistics



QFD in Decision Making

Customer Orientation

 Lean Six Sigma

 Agile Processes

 Project Estimations

 Transfer Functions

- QFD is much slower and less attractive for decision making
 - You cannot detect which important topic you missed
 - Except sometimes thanks to the Convergence Gap
 - If you cannot find the valid Eigenvectors for the matrix
- However, it is much easier to explain decisions taken by some QFD deployment than those with AI

- QFD has no understanding of natural language and does not produce fake images
 - It is less attractive for writing fake papers, essays, and exams
 - It is not generative
- Maybe it is possible to combine QFD with some version of an LLM
 - Provided it does Reference-augmented Generation (RAG)
 - Instead of hallucinations

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QFD is slow and expensive for decision making, that should go fast. QFD is not good at considering other influential topics not seen by experts. AI simply has higher capacity and considers everything – including the famous glitch when an AI that was trained to distinguish wolves from dogs looked at pictures whether there was snow. All wolf pictures in the training set incidentally were taken in winter with snow.

QFD

Cause-effects vs. Statistics

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QFD in Product Development

Customer Orientation

 Lean Six Sigma


 Agile Processes

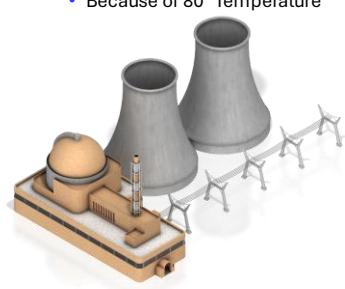
 Project Estimations

 Transfer Functions

- QFD in Product Development
 - ➔ Needs experts
 - ➔ Experts are rare species
 - ➔ But it's fun & sustainable

- AI in Product Development
 - ➔ AI needs many Nuclear Power Plants
 - ➔ However, AI only produces similar designs to existing designs
 - Because of statistics
 - Because of 80° Temperature





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While I have no big hopes for QFD in decision making, it has big advantages in product development. QFD-designed products easily gain market share and are successful, innovative, and attractive, while AI produces always more of the same. Statistics do not generate new designs, even when guided by customer needs. Customers usually want more of the existing for less money; progress is less important.

Nor is sustainability.

One point to mention in favor of AI: Sometimes, gut feeling is better than reasoning (Gigerzer 2007). ANNs must rely exclusively on their gut feeling, because the biological basis of gut feeling is learning from experience, just like ANNs do.

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Questions?

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Search for "Managing" and "Testing"

Managing Complexity
Uncover the Mysteries with Six Sigma Transfer Functions
Thomas Michael Fehlmann
Logos Press Berlin 2016

Autonomous Real-time Testing
Testing in Real-time Environments and Other Complex Systems
Thomas Michael Fehlmann
Logos Press Berlin 2020

The speaker has published quite a bit on the subject together with Eberhard Kranich in Duisburg – e.g., in QFD symposia, at SW metrics conferences like IWSM / Mensura; in quality management and testing conferences, also Lean Six Sigma Conference in Glasgow, Strathclyde and Zurich and in the ATINER series of scientific publications.

Managing Complexity appeared 2016 in Logos Press, Berlin:

<https://www.logos-verlag.com/cgi-bin/buch?isbn=4406>

Autonomous Real-time Testing is available since January 2020 with the same publisher: <https://www.logos-verlag.com/cgi-bin/buch?isbn=5038>