



Artificial Intelligence

AI Case Studies & AI Project Management

Prof. Dr. habil. Jana Koehler

Artificial Intelligence - Summer 2020

Agenda

- Digital Transformation and AI
- Beyond Design Thinking: Feasible - Viable - Desirable
- Discussion of Projects
 - Elevator Destination Control
 - Cable Tree Wiring
 - Rigi Bot Tourist Information Service
 - IT Service Support
- Lessons Learned
- Bachelor and Master Thesis Projects at AI Chair:
 - <https://jana-koehler.dfki.de/teaching/>

Project Overview



	Destination Control 1998-2001	Cable Wiring 2012-2020	Rigi Bot 2016/2017	IT Service Support 2016/2017
Business Driver	Performance Increase	Production Optimization & Automation of Services	Defend against international platforms & digital services	Keep up with Complexity and Growth
Environment	Known, Deterministic Observable, single agent	Known, Stochastic, Partially Observable, single agent	Partially known, Stochastic, Partially Observable, multi Agent	Partially known, deterministic, observable, multi agent
AI Technology	Heuristic Search	Stochastic Search	Supervised Learning	Supervised Learning
AI Challenge	Search algorithm	Modeling	Bias in pretrained models	Data quality, solution integration
Other Challenges	Customer Acceptance & Integration	Data standardization, testing	Skills, data, privacy, integration	Integration, data quality, skills, fit to existing business

Digital Transformation and AI

Digital Transformation Enables + Needs AI

since 00s: arbitrary data
in massive amounts

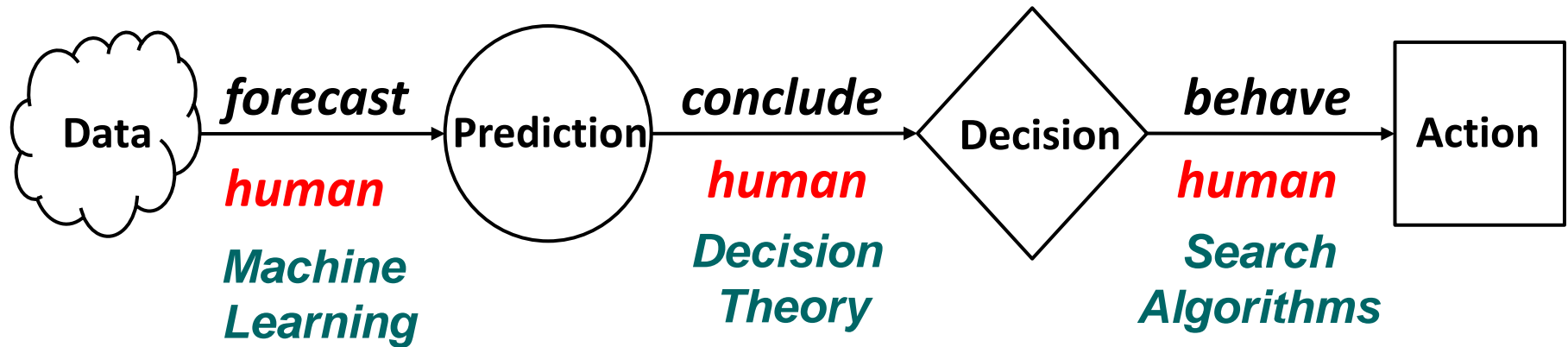
- revolutionize business models and processes

60/70s: selected data
in small amounts

- support business processes



Prediction - Decision - Action

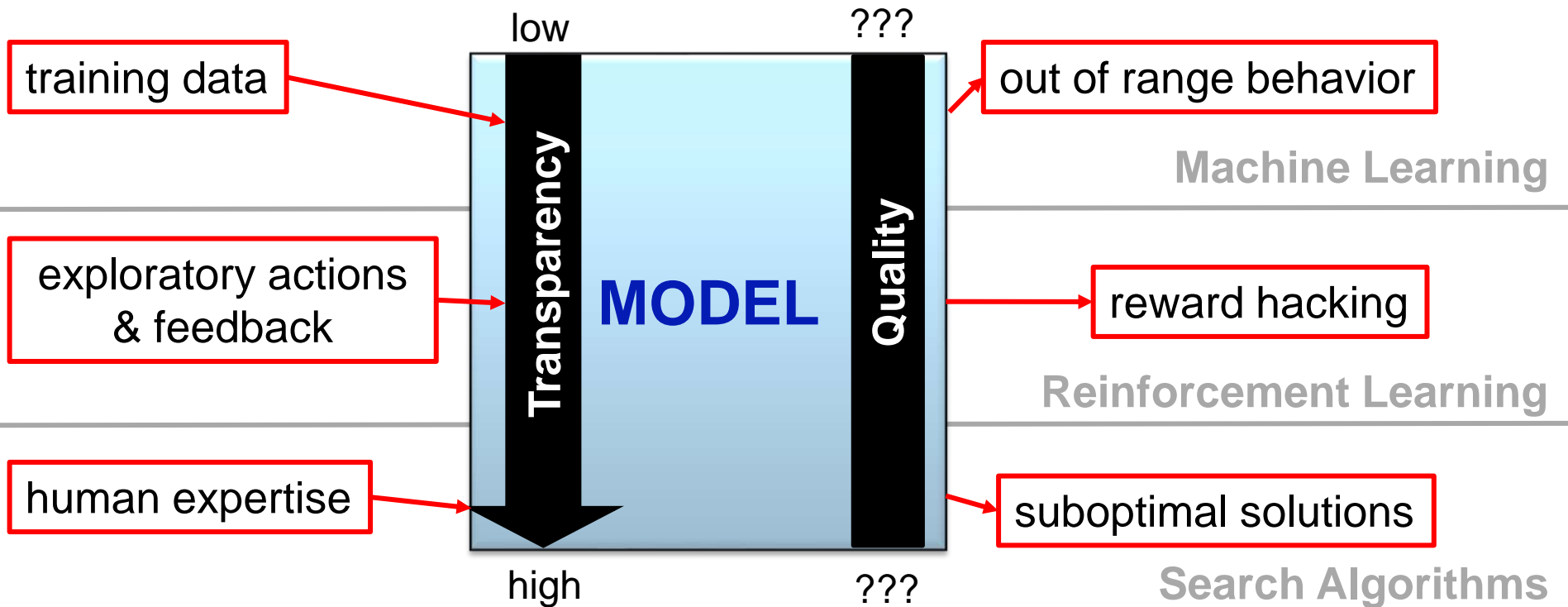


“Big data” is high-volume, -velocity and -variety information assets that demand

- *cost-effective, innovative forms of information processing*
- *for enhanced insight and decision making*

Gartner 2011

Transparency and Quality of Models influence Risks



Hype Hurts: Steering Clear of Dangerous AI Myths

Published: 03 July 2017 ID: G00324274

<https://www.gartner.com/smarterwithgartner/steer-clear-of-the-hype-5-ai-myths/>

Analyst(s): [Tom Austin](#) | [Alexander Linden](#) | [Mike Rollings](#)

- Myth 1: Buy an AI to Solve Your Problems
- Myth 2: Everyone Needs an AI Strategy or a Chief AI Officer
- Myth 3: Artificial Intelligence Is Real
- Myth 4: AI Technologies Define Their Own Goals
- Myth 5: AI Has Human Characteristics
- Myth 6: AI Understands (or Performs Cognitive Functions)
- Myth 7: AI Can Think and Reason
- Myth 8: AI Learns on Its Own
- Myth 9: It's Easy to Train Applications That Combine DNNs and NLP
- Myth 10: AI-Based Computer Vision Sees Like we Do (Or Better)
- Myth 11: AI Will Transform Your Industry — Jump Now and Lead
- Myth 12: For the Best Results, Standardize on One AI-Rich Platform Now
- Myth 13: Maximize Investment in Leading-Edge AI Technologies
- Myth 14: AI Is an Existential Threat (or It Saves All of Humanity)
- Myth 15: There Will Never Be Another AI Winter

Consider This ...

**Secondary effects
will be more
disruptive than the
initial digital change**

DD5

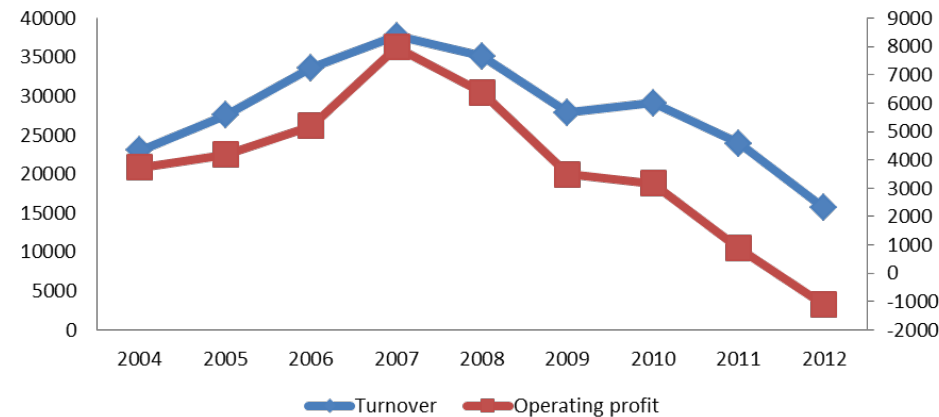


Secondary Effects of Innovation are more Disruptive than the initial Digital Change



<https://www.youtube.com/watch?v=MnrJzXM7a6o>

**Nokia mobile phone business
2004-2012 (million euros)**



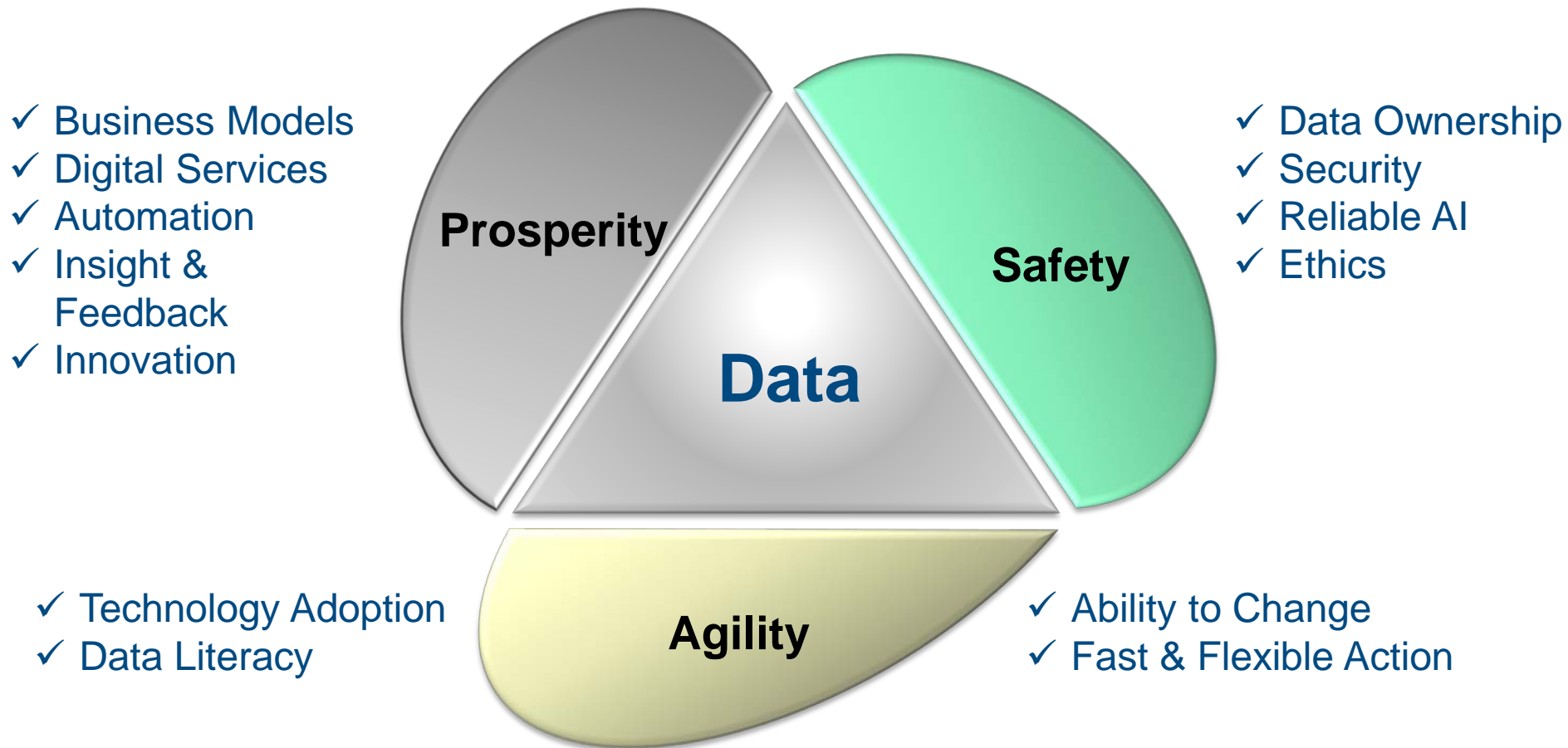
<http://disruptiveinnovation.se/?cat=16>

Banking is Necessary, Banks are Not.

Bill Gates, 1994

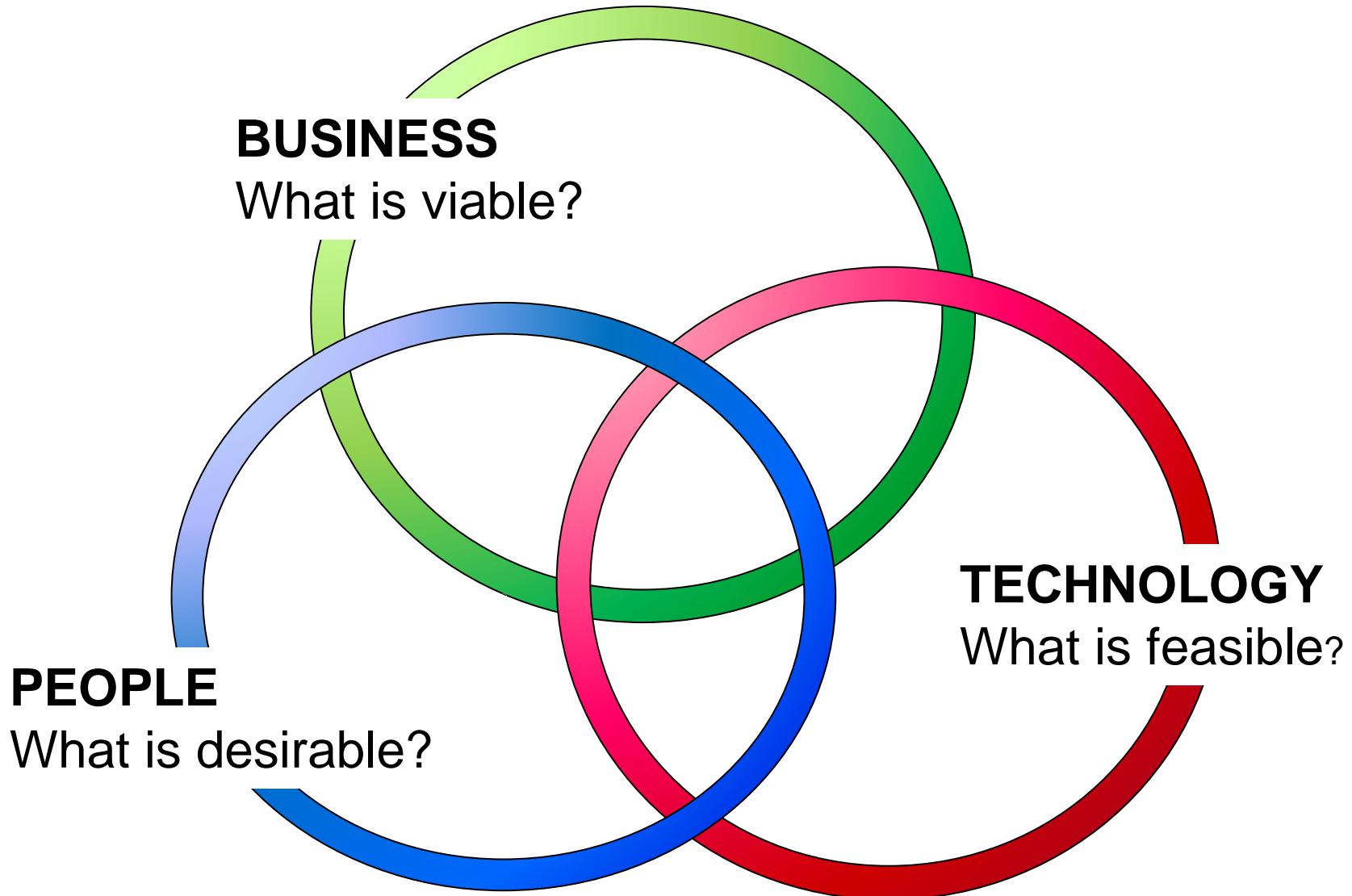
loss of customer contact + inattractive products
are perfect to drive an enterprise out of business

Central Role of Data Strategy in an Enterprise

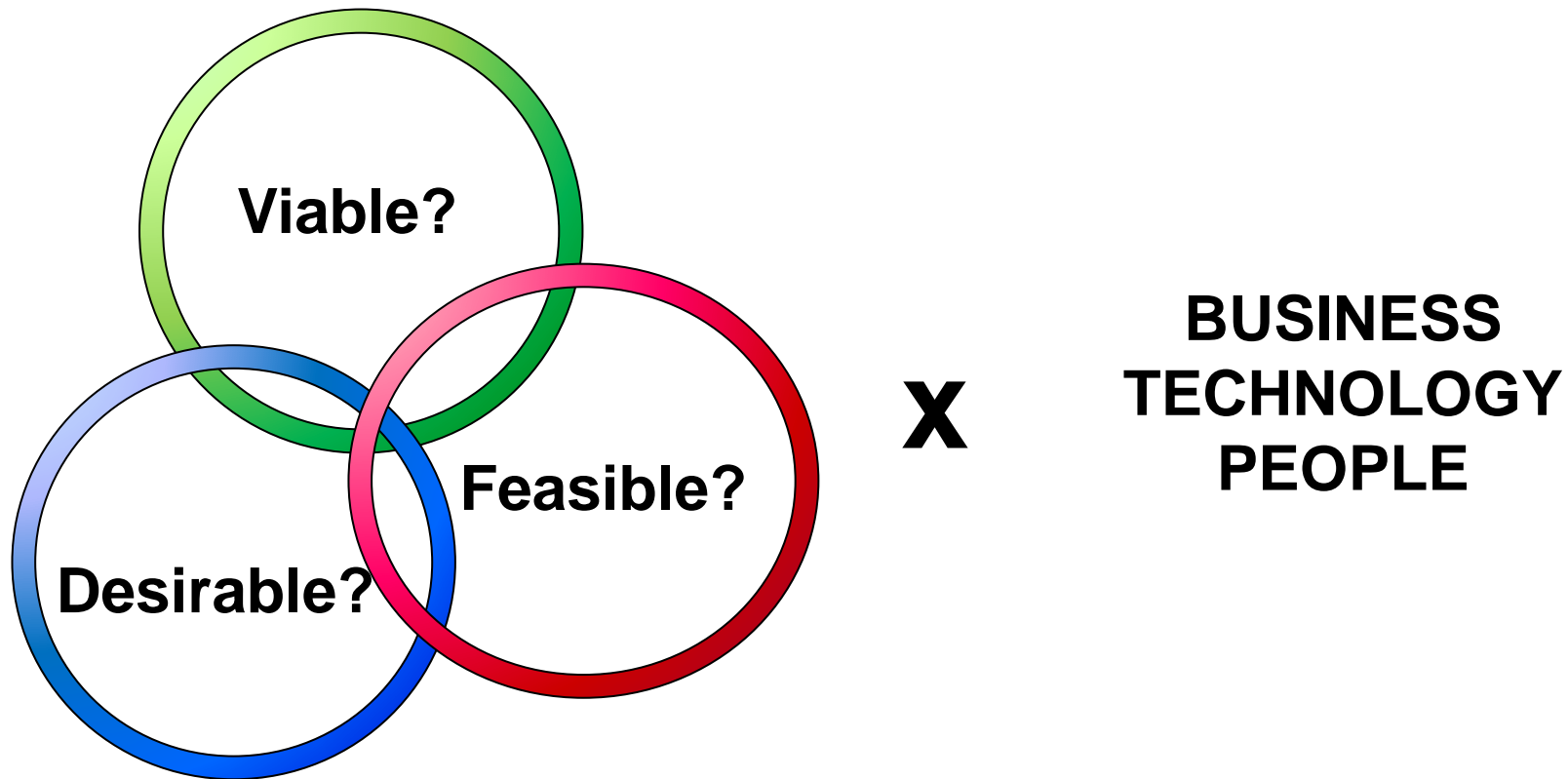


Beyond Design Thinking: Feasible - Viable - Desirable

3 Essential Dimensions that need to be Managed



AI Requires to Rethink all Aspects across all 3 Dimensions



A circle with a green-to-yellow gradient border.

Viable?

TECHNOLOGY: hype or lasting technology stack?

BUSINESS: profitability in the mid-/long-term?

PEOPLE: organizational/cultural change required/possible?

A circle with a blue-to-purple gradient border.

Desirable?

TECHNOLOGY: acceptable level of risk?

BUSINESS: (r)evolution of business model?

PEOPLE: (ethically) wanted by customers and employees?

A circle with a red-to-pink gradient border.

Feasible?

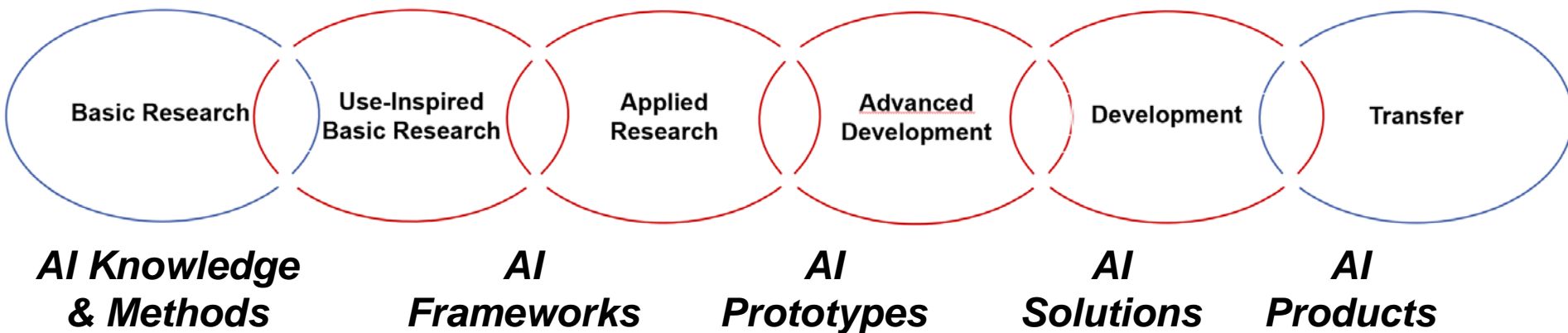
TECHNOLOGY: works under realistic conditions (EA, data)?

BUSINESS: necessary investments possible?

PEOPLE: skills available?

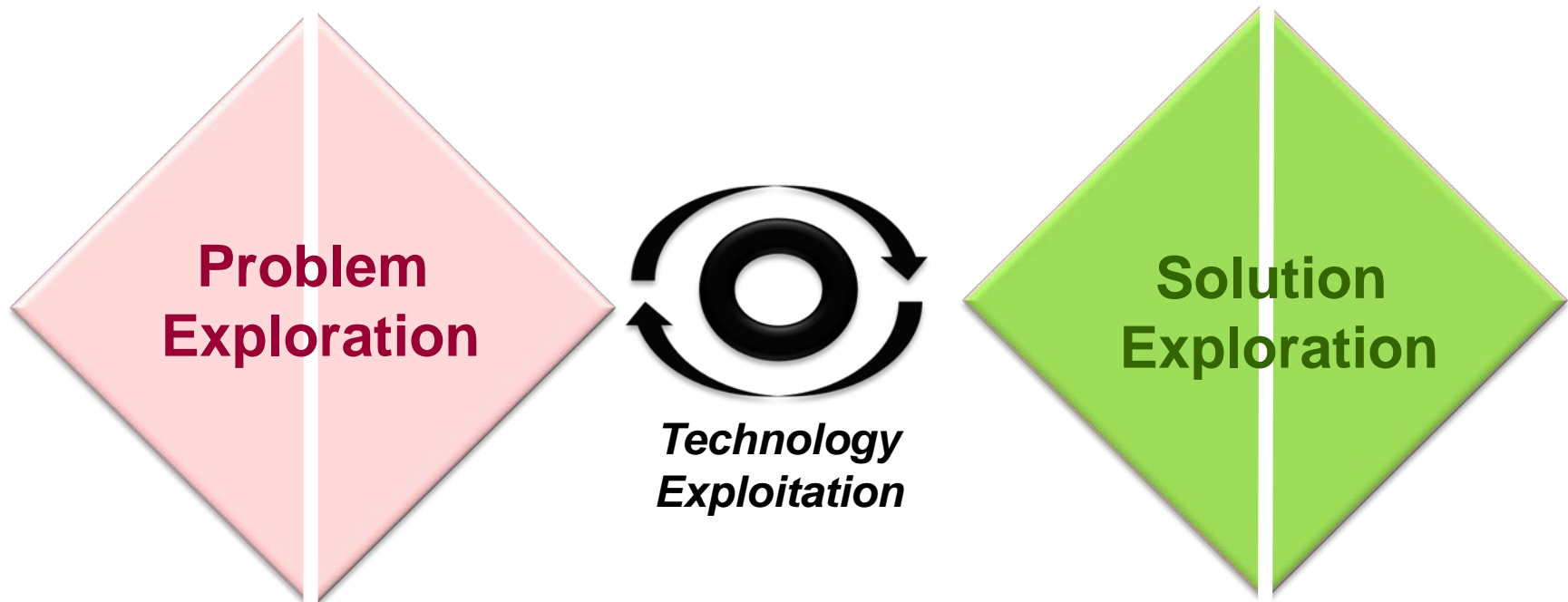
Mastering the Innovation Chain

- Innovation still takes 10-20 years ...
- From insight to impact
- Fueling and leveraging the innovation chain is challenging

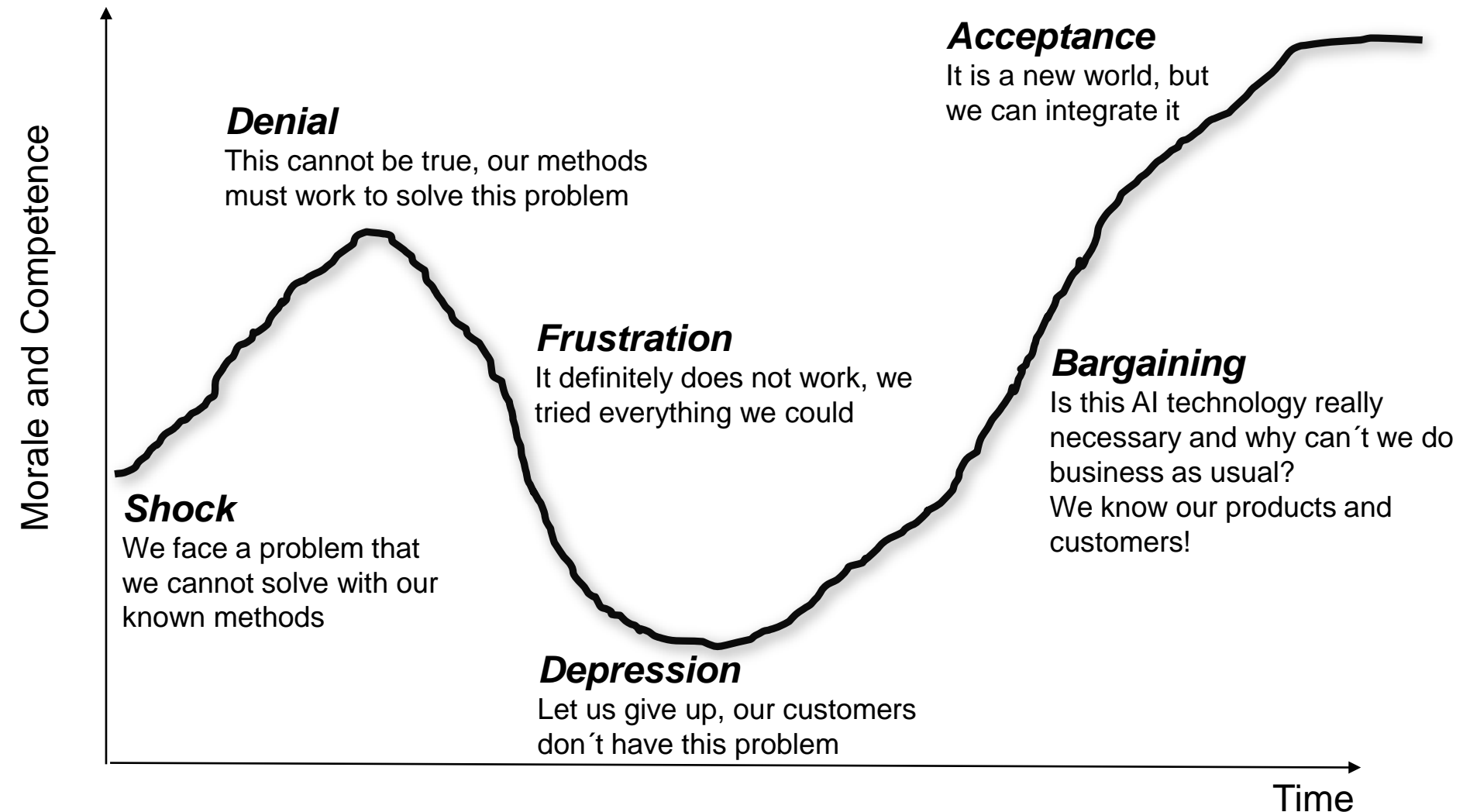


Exploitation vs. Exploration

- Manage the balance between deepening the problem understanding and moving forward with technology evaluation and decision-taking towards the final solution architecture & technology exploitation



Kübler-Ross Model of Change and Transformation (for AI) ☹️



Real-World Environments are Complex - How To Simplify?



Environments that are unknown, partially observable, nondeterministic, stochastic, dynamic, continuous, and multi-agent are the most challenging

Elevator Destination Control

Conventional Elevator Control

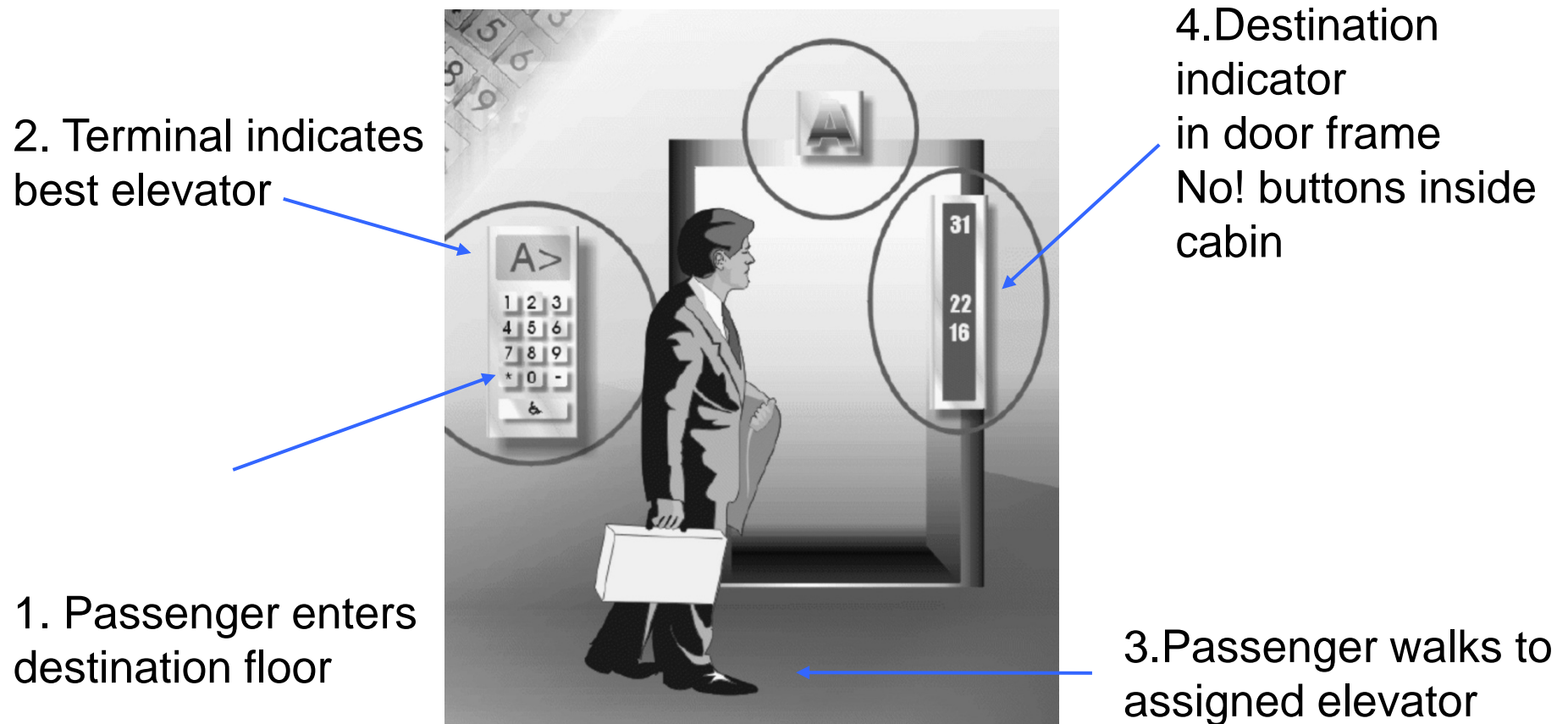


1. Outside the cabin:
One or two buttons to
call elevator

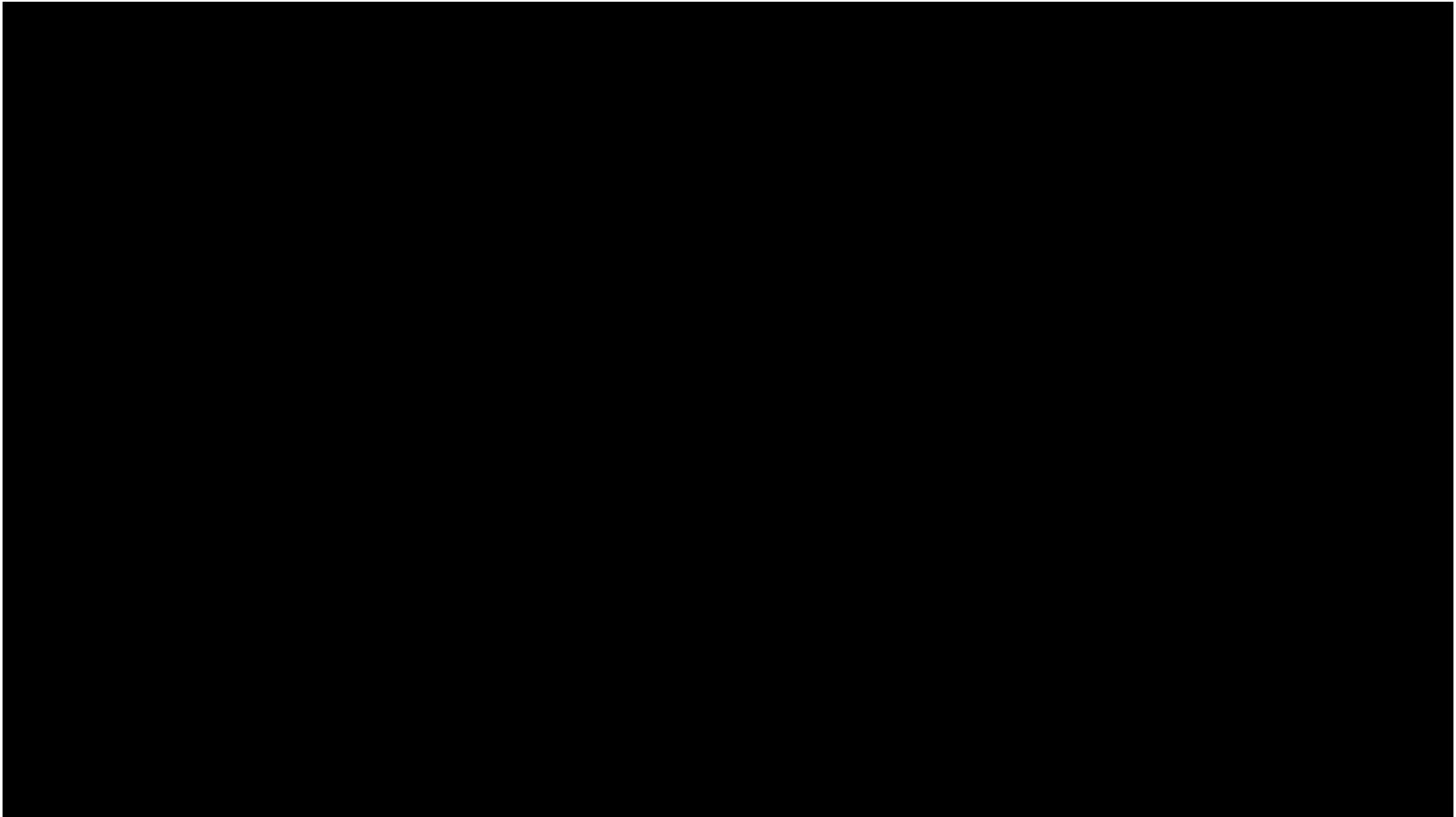


2. Inside the cabin:
One button per floor

Alternative: Destination Control



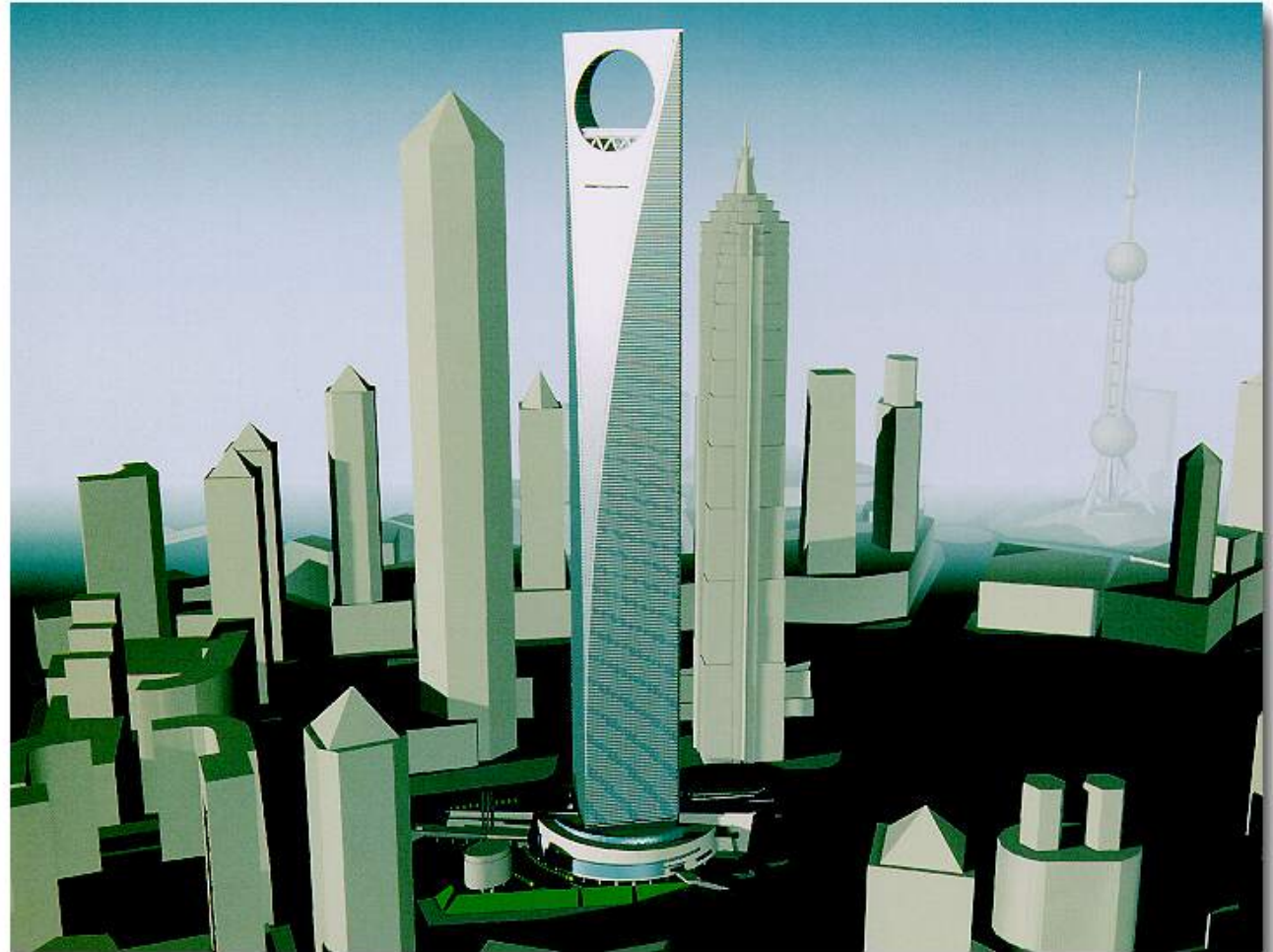
Destination Control



<https://www.youtube.com/watch?v=Q8aaz3NTvgg>

Main Driver 1: Mixed Usage of Buildings

94-93	observation
90-61	hotel
79-56	office
55-49	hotel
55-6	office
3	shops
2	hotel lobby
1	office lobby
-1 to -3	parking



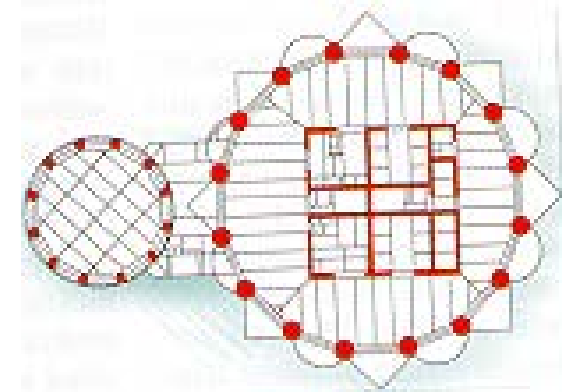
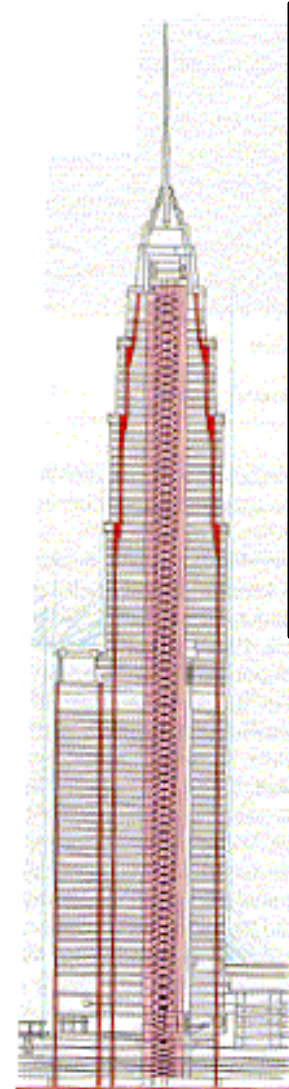
WTB

Shanghai World Financial Center

Illustration: Mori Building Co. Ltd., Japan

Main Driver 2: Increase Customer Value

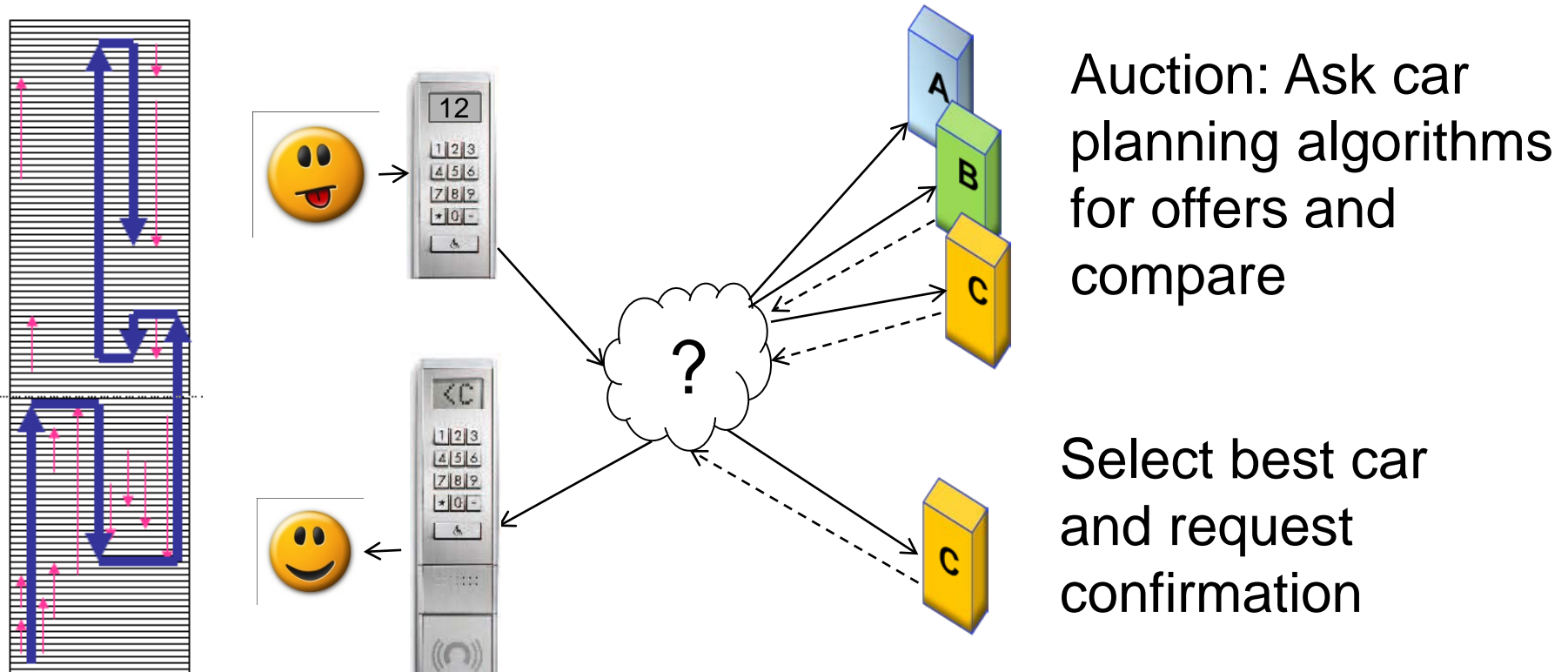
- Less space
- Less energy costs
- Higher performance
 - Less waiting time
 - Faster traveling
 - More direct travels
- Diversification of products
 - New services
 - Customization
- Key in double deck market



The AI Challenge

J. Koehler, D. Ottiger: An AI-based Approach to Destination Control in Elevators, AI Magazine, 23(3): pages 59-78, Fall 2002.

- Find an optimal tour
 - serve all passengers as fast as possible
 - maximize transportation capacity, minimize energy costs



A*-like heuristic backtracking search over $10^{12} - 10^{14}$ states

PDDL and the International Planning Competition 2000

```
(:action stop
:parameters (?f - floor)
:precondition
(and (lift-at ?f)
(implies (exists (?p - conflict_A)
(or (and (not (served ?p)) (origin ?p ?f))
(and (boarded ?p) (not (destin ?p ?f)))))
(forall (?q - conflict_B)
(and (not (boarded ?q))
(or (served ?q) (not (origin ?q ?f)))))
(implies (exists (?p - conflict_B)
(or (and (not (served ?p)) (origin ?p ?f))
(and (boarded ?p) (not (destin ?p ?f)))))
(forall (?q - conflict_A)
(and (not (boarded ?q))
(or (served ?q) (not (origin ?q ?f)))))
(implies
(exists (?p - never_alone)
(or (and (origin ?p ?f) (not (served ?p)))
(and (boarded ?p) (not (destin ?p ?f)))))
(exists (?q - attendant)
(or (and (boarded ?q)
(not (destin ?q ?f))
(and (not (served ?q)) (origin ?q ?f)))))
(forall (?p - going_nonstop)
(implies (boarded ?p) (destin ?p ?f)))
(or (forall (?p - vip) (served ?p))
(exists (?p - vip)
(or (origin ?p ?f) (destin ?p ?f))))
(forall (?p - passenger)
(implies (no-access ?p ?f) (not (boarded ?p)))))
:effect (and
(forall (?p - passenger)
(when (and (boarded ?p) (destin ?p ?f))
(and (not (boarded ?p)) (served ?p))))
(forall (?p - passenger)
(when (and (origin ?p ?f) (not (served ?p)))
(boarded ?p)))))
```

Figure 4: STOP Operator in PDDL Syntax.


COMPETITION IN ARTIFICIAL INTELLIGENCE

**LiftLoc®/Miconic 10
Destination Control by
Schindler**

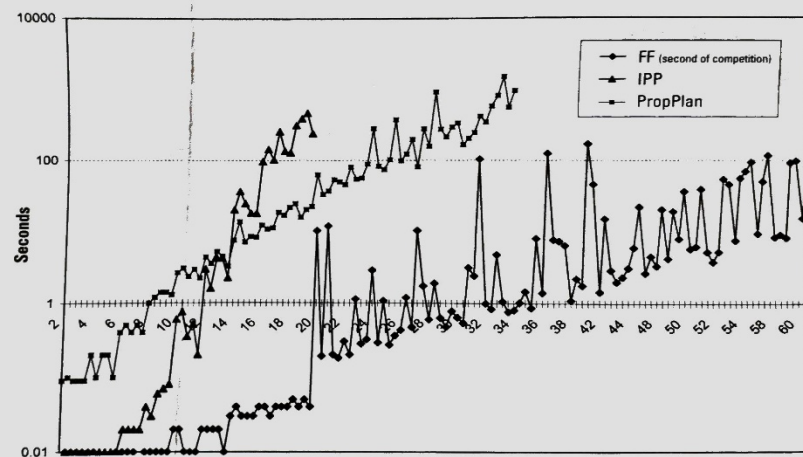
**A Challenge for Intelligent
Planning Systems**

The LiftLoc® destination control system newly developed by Schindler with its unique variety of passenger services provides an ideal experimental platform for research in Artificial Intelligence (AI) planning. That is why the LiftLoc® concepts and ideas have been made available by Schindler R&D and were used as the final challenge in the recent International Planning Competition.

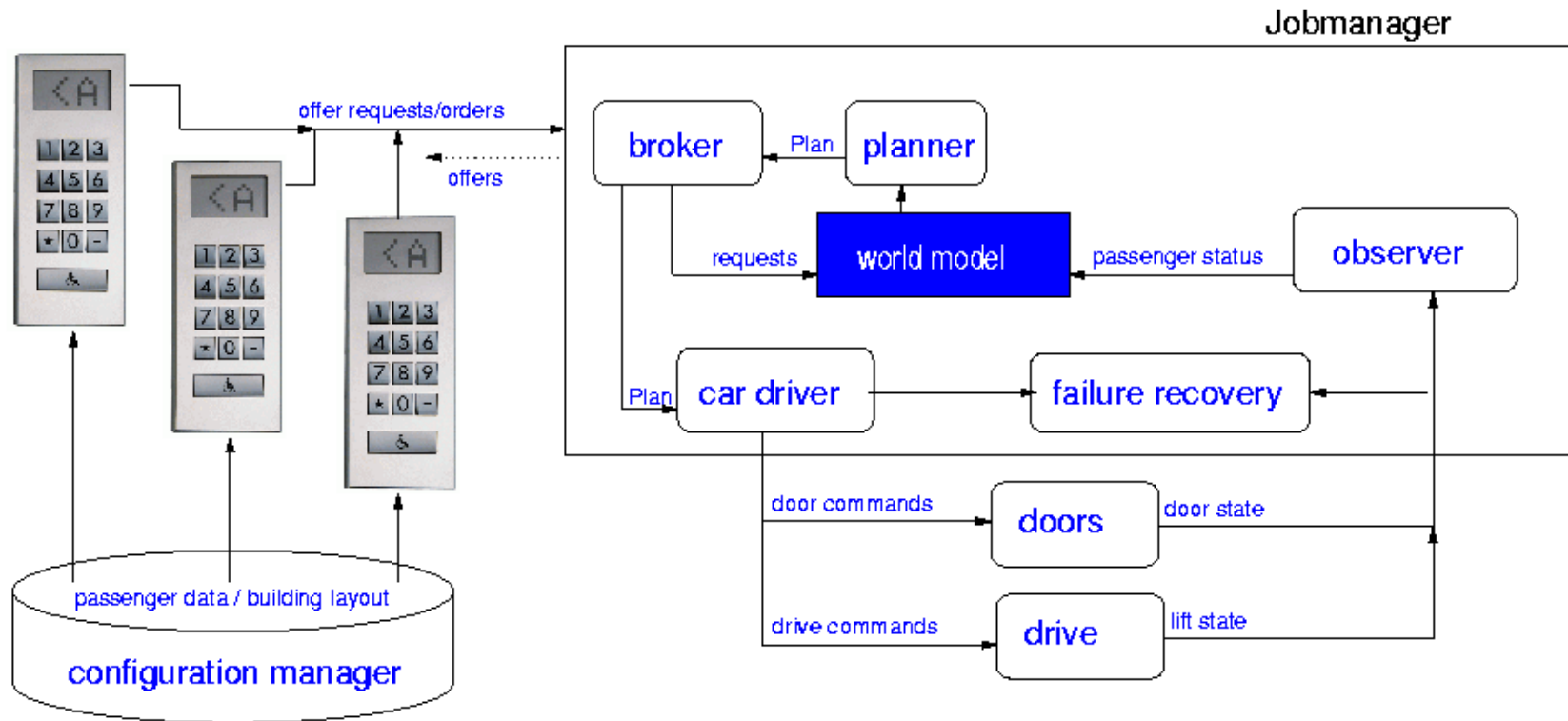
In the last two issues of the R&D Interface we talked about the evolution of the passenger interface in



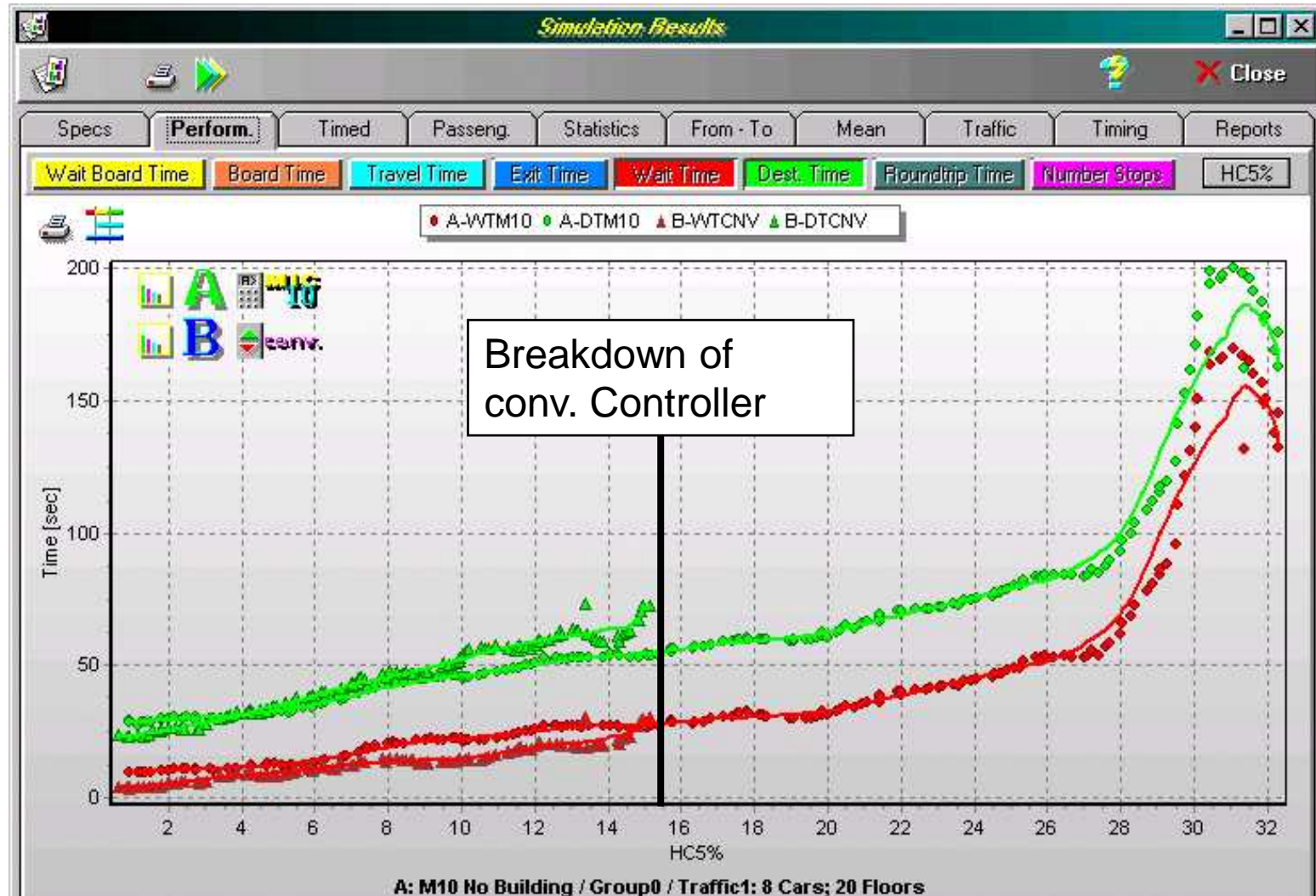
PD Dr. habil. Jana Köhler of Schindler R&D hands over the award to Jörg Hoffmann, developer of the FF planner, PhD student at the University of Freiburg (Germany). In the back, Prof. Fahiem Bacchus, University of Toronto (Canada), the head of the competition committee.



Solution Architecture



50 % Increased Capacity during an Up-Peak Pattern



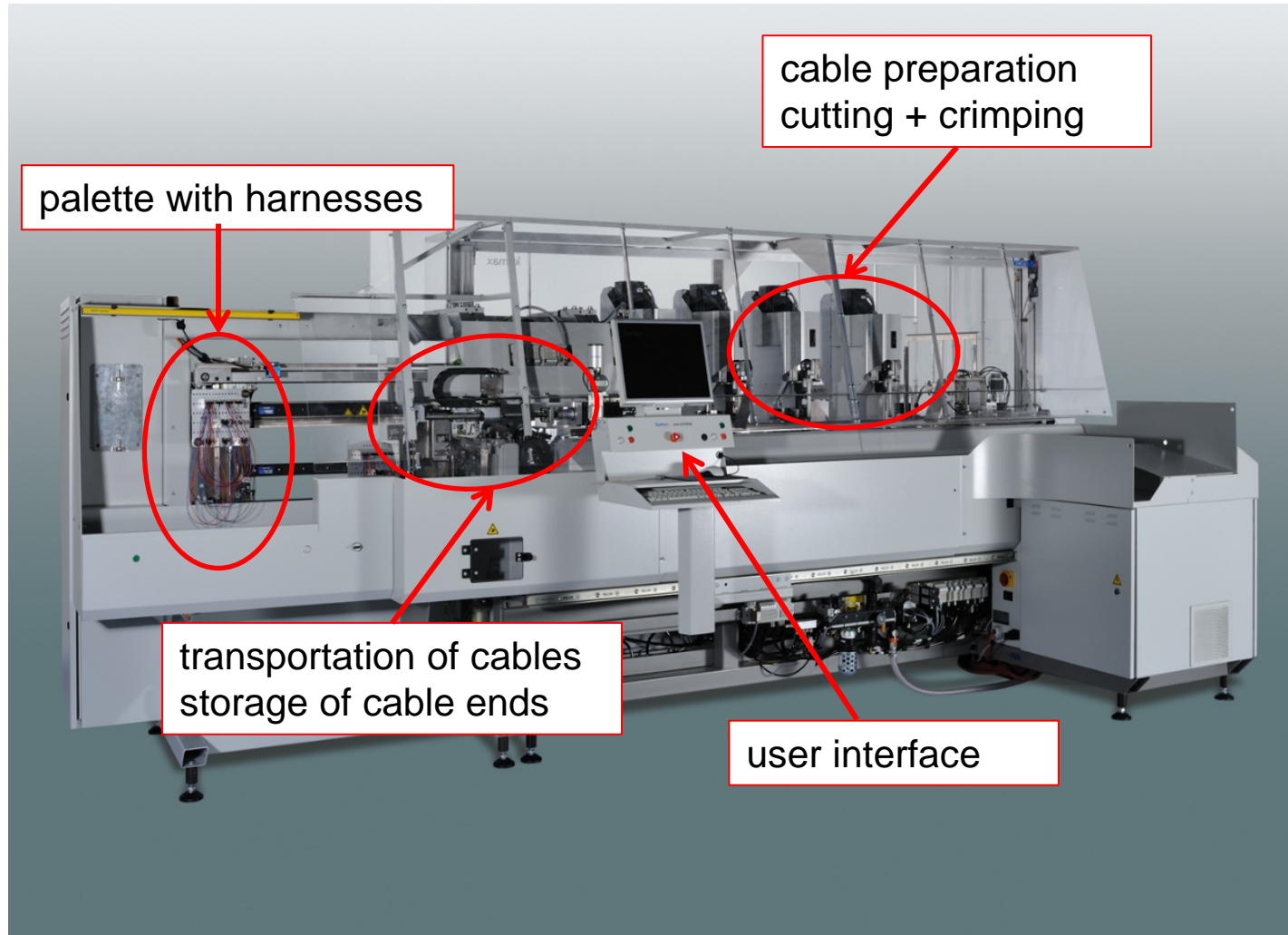
Towards Multicar Elevators



<https://www.urban-hub.com/technology/new-era-of-elevators-to-revolutionize-high-rise-and-mid-rise-construction/>

Cable Tree Wiring

komax Zeta Maschine

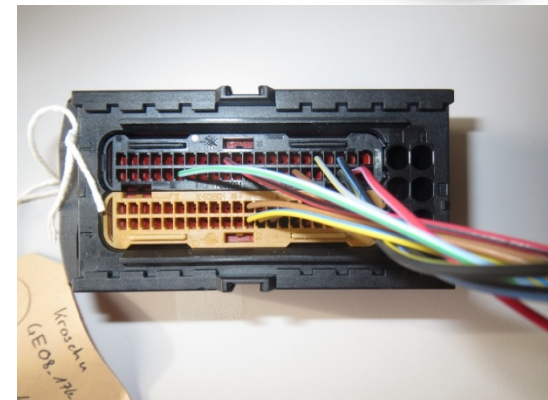
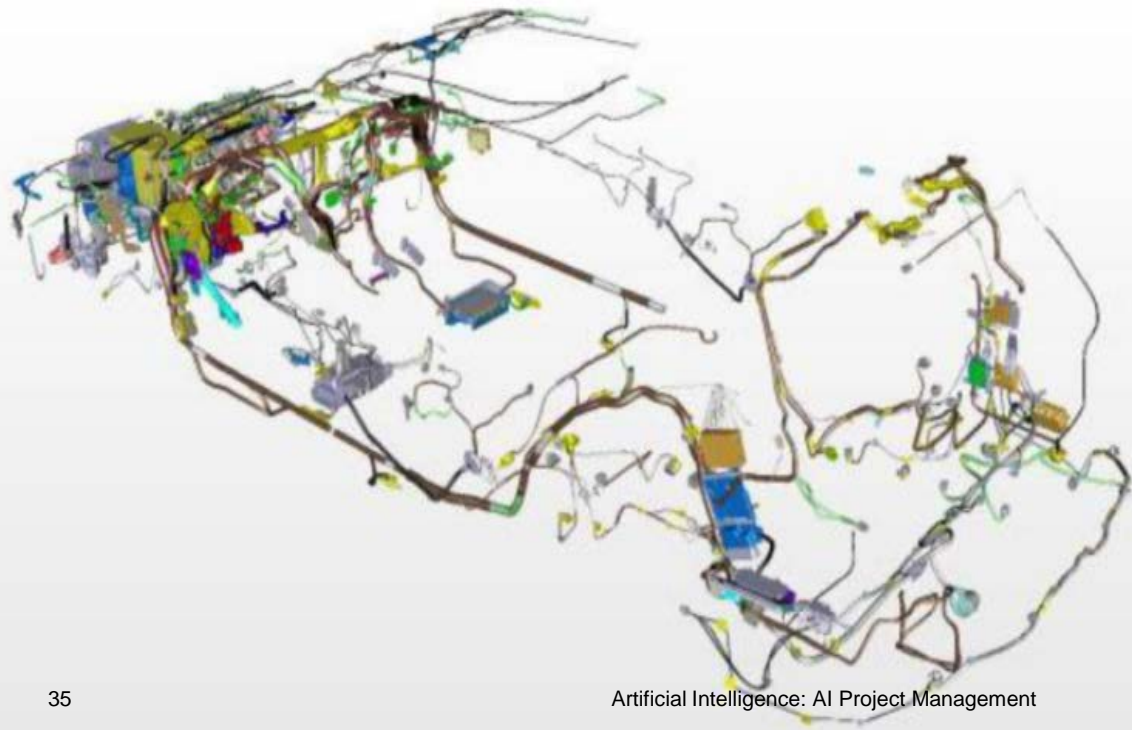


Cable Tree Wiring



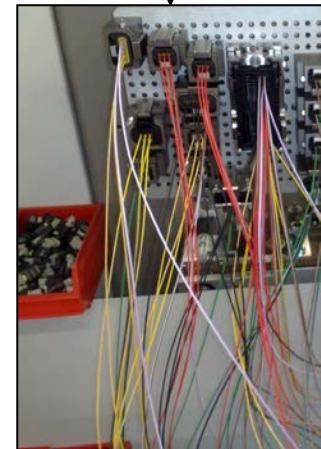
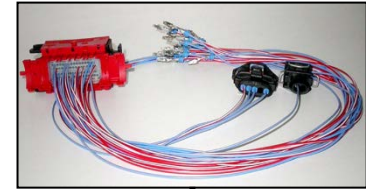
Cable Trees in VW Golf 7

- 14 cable trees with total 1633 cables, 50 % could be manufactured on Zeta machines
- approx. 1 million cars per year

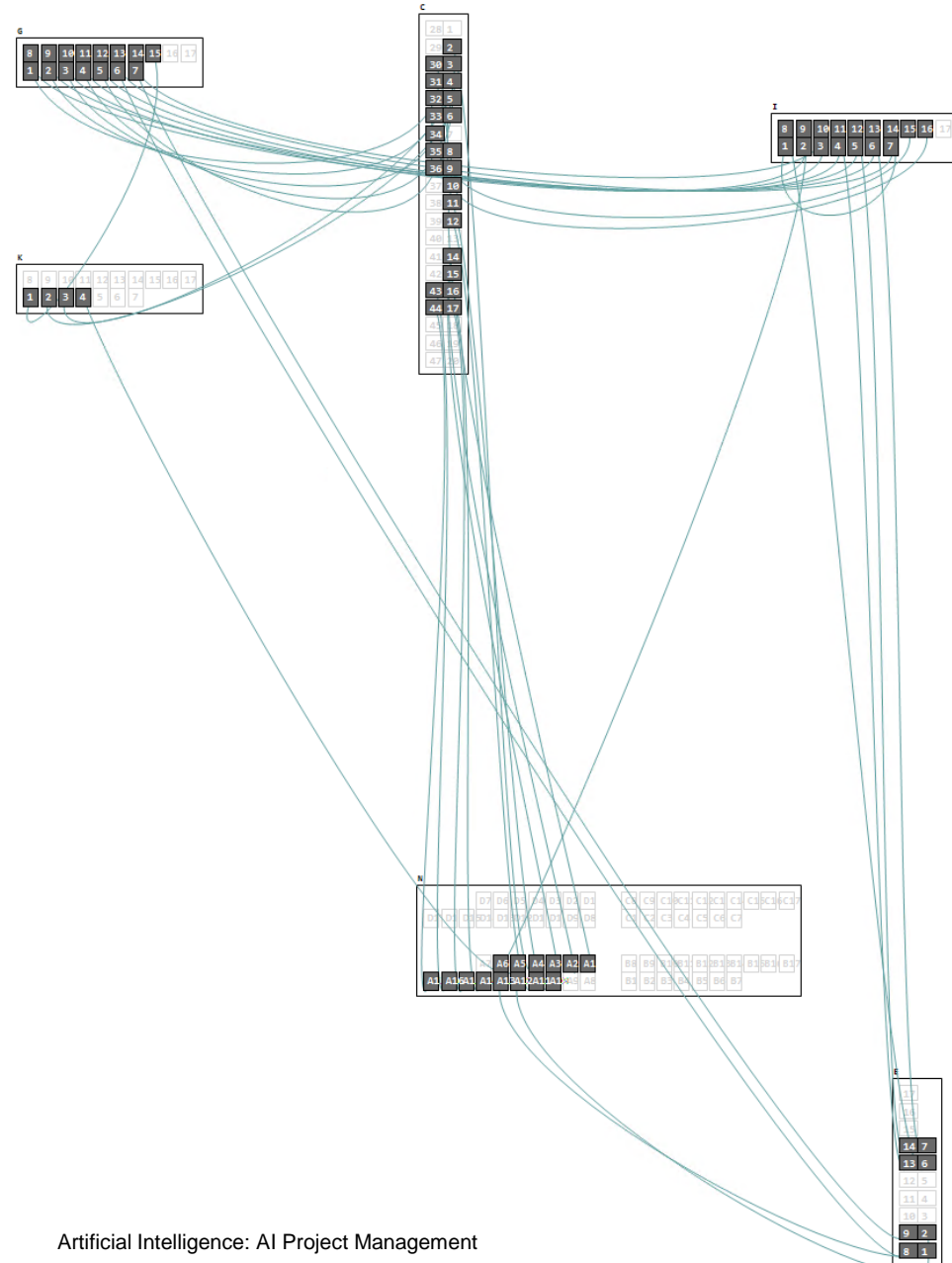


Towards Self-Programming Machines

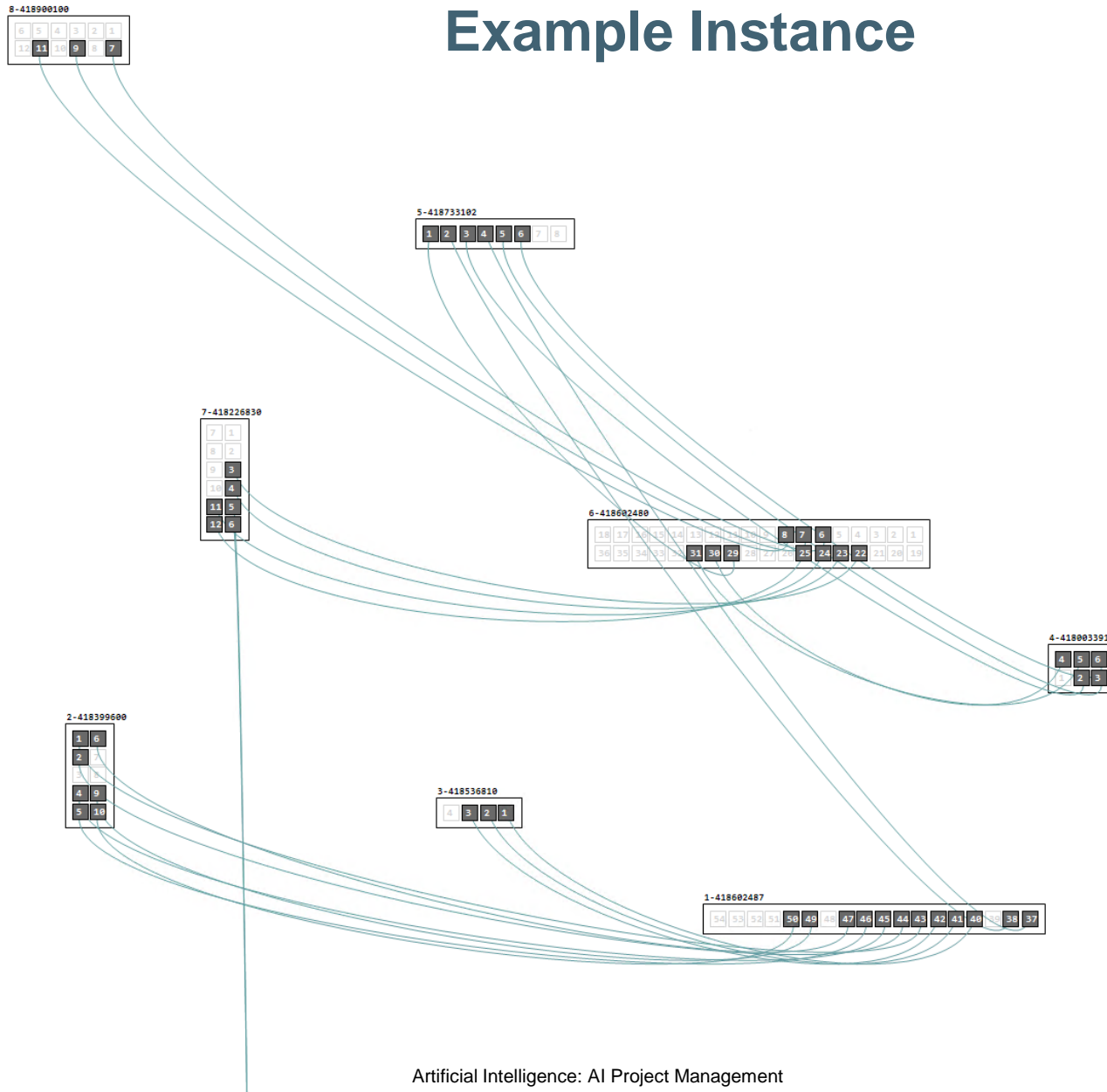
- Proprietary descriptions of cable trees, VDA Vehicle Electric Container VEC standard expected for adoption over next decade
- Layout problem: placement of harnesses on palette
- Permutation problem: sequential order of wiring steps



Example Instance



Example Instance



The AI Challenge

- Single agent, but dynamic environment
- Partially observable
- Non-deterministic actions
- Complex physics and unknown model of cable behavior
- Huge search space:
 - 40 Cables = $80! = 7 \times 10^{118}$
 - 80 Cables = $160! = 4 \times 10^{284}$
- High integration effort
- Technicians feel threatened by technology

The Permutation Problem

job c_i cable end i inserted into cavity c

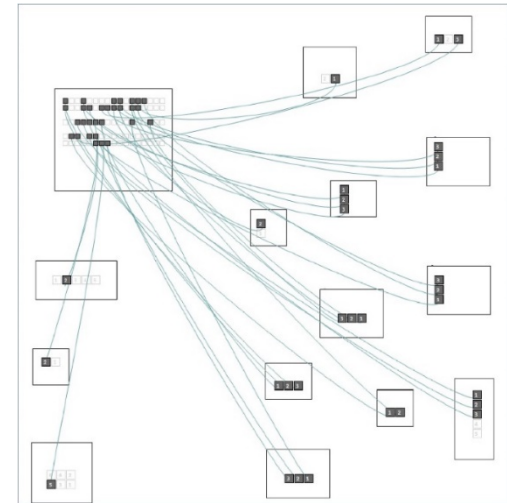
job pairs $\langle c_i, c_j \rangle$

b job pairs: $i = 1 \dots b$ and $j = b + 1 \dots 2b$

n "one-sided" cable ends: $i = 2b + 1 \dots 2b + n$

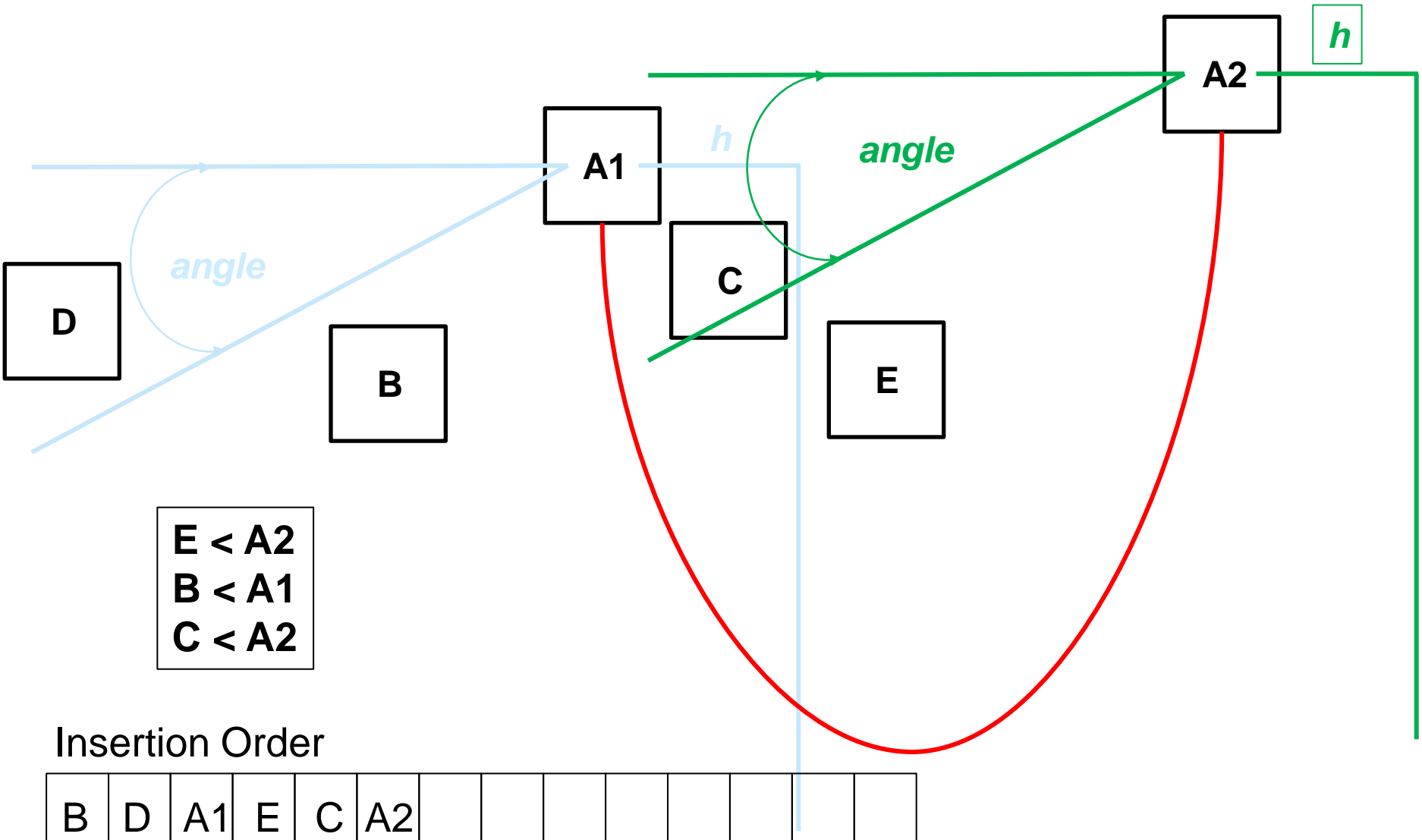
\mathcal{P} of length $k = 2b + n$

$p(c_i)$ position of job c_i in \mathcal{P}



Many routing, scheduling, assignment problems give rise to permutation problems

Approximating Cable Fall and Robot Arm Blocking



Constraints

Atomic precedence constraints (hard and soft)

$$c_x \triangleleft c_y \in \mathcal{A} \quad c_x, c_y \in [1 \dots k], x \neq y \quad \mathcal{P} \text{ if and only if } \mathcal{P} \vdash p(c_x) < p(c_y)$$

Disjunctive precedence constraints

$$(c_x \triangleleft c_y \vee c_w \triangleleft c_v) \in \mathcal{D} \quad c_x, c_y, c_w, c_v \in [1 \dots k] \quad \mathcal{P} \vdash p(c_x) < p(c_y) \text{ or } \mathcal{P} \vdash p(c_w) < p(c_v)$$

$$\mathcal{D}_1 : c_k \triangleleft c_i \vee c_k \triangleleft c_j$$

$$\mathcal{D}_2 : c_k \triangleleft c_i \vee c_j \triangleleft c_k$$

Direct successor constraints

$$c_i \blacktriangleleft c_j \in \mathcal{S} \quad c_i, c_j \in [1 \dots 2b], i \neq j \quad \mathcal{P} \vdash p(c_j) = p(c_i) + 1 \text{ or } \mathcal{P} \vdash p(c_j) < p(c_i)$$

Related to TSP with tour-dependent edge costs and coupled task scheduling

Example

As an illustrating example of a constraint set consider a cable tree with cables A , B and C , where A and B are two-sided cables defining the job pairs $\langle c_1, c_3 \rangle$ and $\langle c_2, c_4 \rangle$ respectively and C is a one-sided cable defining the job c_5 . The instance has parameters $k = 5$ and $b = 2$. We are further given the following constraints for this example instance:

$$c_3 \triangleleft c_4$$

$$c_4 \triangleleft c_1$$

$$c_5 \triangleleft c_4$$

$$c_2 \triangleleft c_5 \vee c_2 \triangleleft c_1$$

$$c_4 \blacktriangleleft c_2$$



Of the $5! = 120$ possible job permutations, only 8 are valid solutions satisfying all the constraints. One example of such a valid solution is the permutation $(c_5, c_3, c_4, c_2, c_1)$.

$$k^3 \cdot S + k^2 \cdot M + k \cdot L + N \tag{6}$$

For the example considered above and the solution $(c_5, c_3, c_4, c_2, c_1)$, this formula returns costs 161 ($S = M = N = 1, L = 2$), which makes this solution one of the two optimal solutions for this problem instance.

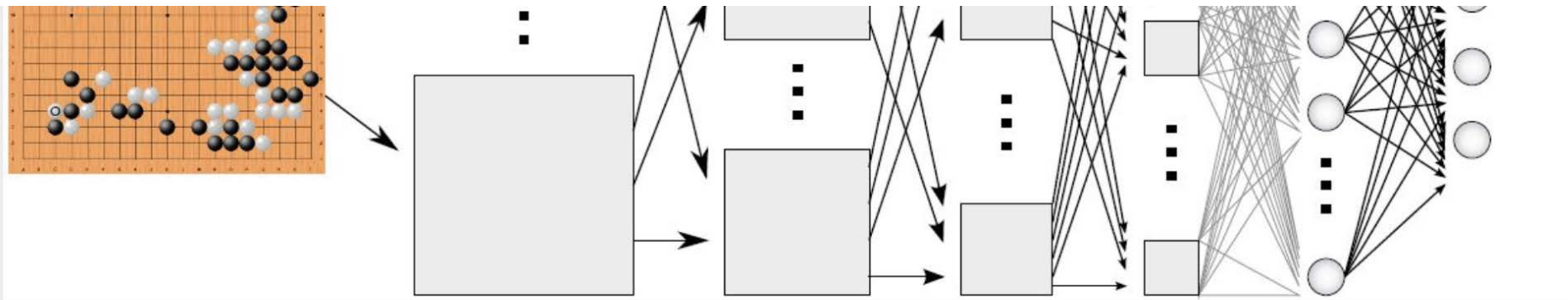
Solvers on CTW Benchmark of 278 Instances

- 205 real-world and 73 artificial instances, includes 22 unsatisfiable instances
- Permutation length 0 .. 198, up to 10,000 atomic and >1000 disjunctive constraints
- 5minute timeout
- CP-SAT solvers
 - IBM Cplex CP Optimizer 12.10
 - Google OR-Tools CP-SAT Solver 7.5.7466
 - Chuffed 0.10.3
- MIP solvers
 - IBM Cplex MIP solver 12.10
 - Gurobi 9.0.1
- OMT solvers
 - Microsoft Z3 4.8.7
 - OptiMathSAT 1.5.1

Solver State	Cplex CP	Chuffed		OR-Tools	
	M_C	M_{Z_1}	M_{Z_2}	FZN_1	FZN_2
optimal	139 (+54)	144	135	224	228
suboptimal	117	85	88	6	5
unsolved	0	26	32	24	21
unsatisfiable	22	22	22	22	22
undefined	0	1	1	2	2
TOTAL Solved	256	229	223	230	233

Rigi Bot

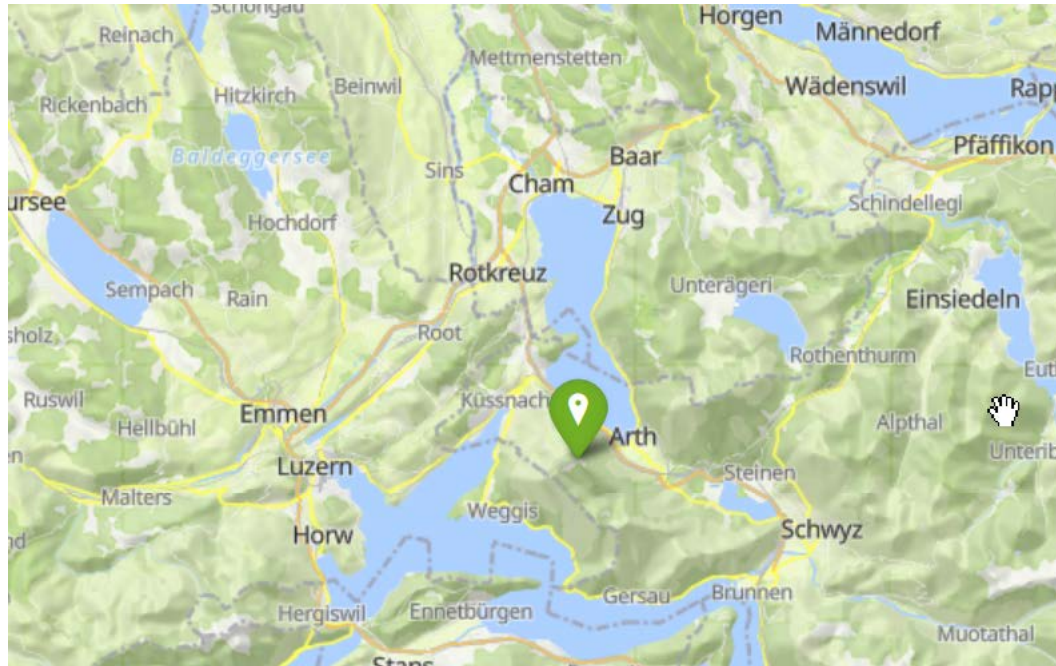
Another Source of Project Motivation



Now any business can access the same type of AI that powered AlphaGo

<https://www.technologyreview.com/the-download/613081/now-any-business-can-access-the-same-type-of-ai-that-powered-alphago>

Rigi Tourist Information Service

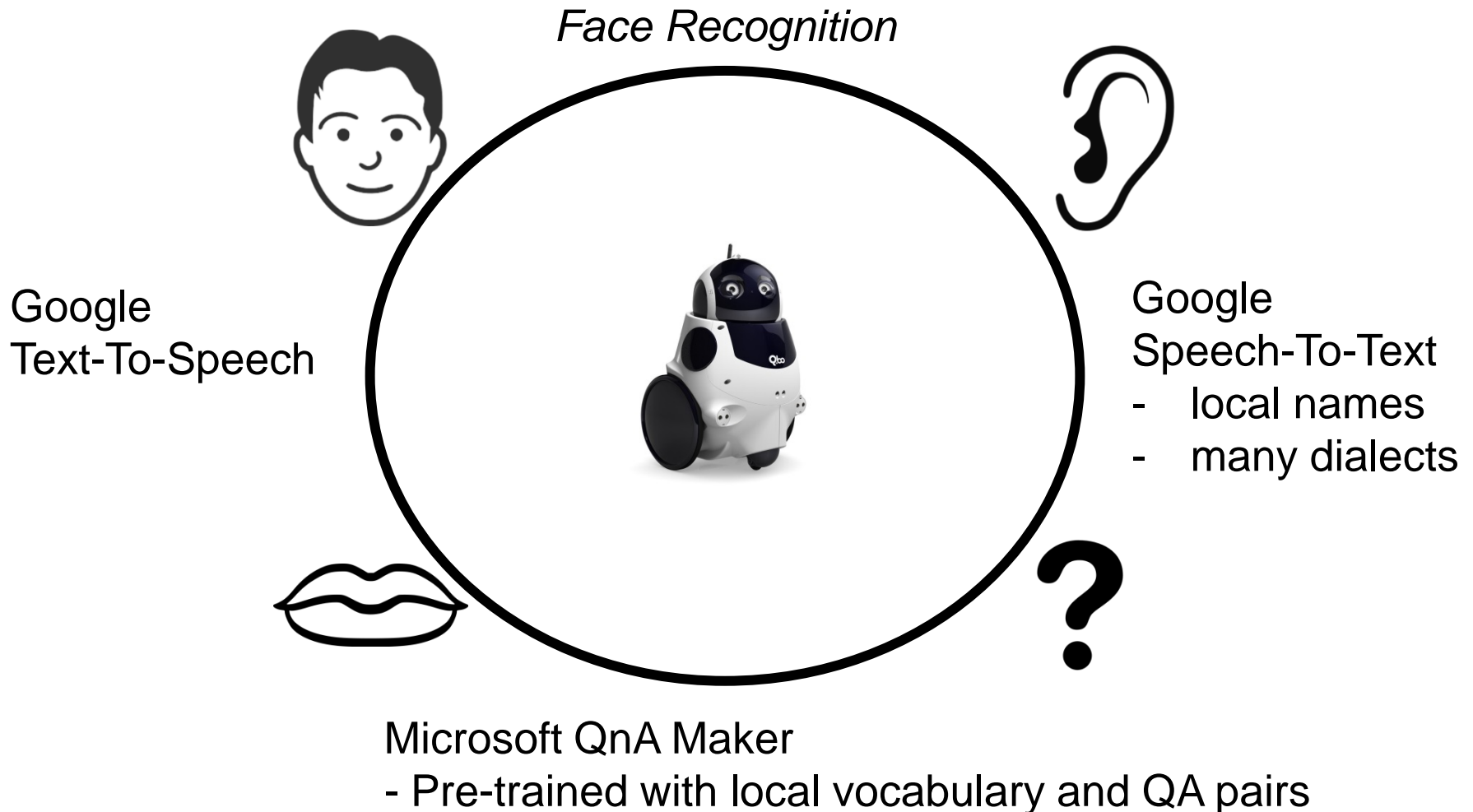


nearly 1 mio visitors per year



The AI Challenge

- Rigi Tourist Guide with Microsoft and Google AI Services



User Interaction



4 Hour Experiment in December 2017

- 477 audio recordings: 303 language, 173 noise

- 252 in English and 51 in German
 - 138 direct questions, rest other conversations
 - 88 correct transcriptions, 59 containing errors
 - 55 social contact interactions, only 33 questions
 - *What do you know?, Can you follow me?, What are you doing here?*
 - Vitznau = Pittsburgh or 7, Weggis = Las Vegas

- After 1 hour, experiment with QnA maker in German was stopped due to long answering times from MS cloud

IT Service Support

Intelligent Process Support in Customer Service

„What is the Situation?“



Scribe

„Who is the Expert?“



Skill Manager

„Where is the Information?“



Background Knowledge Worker

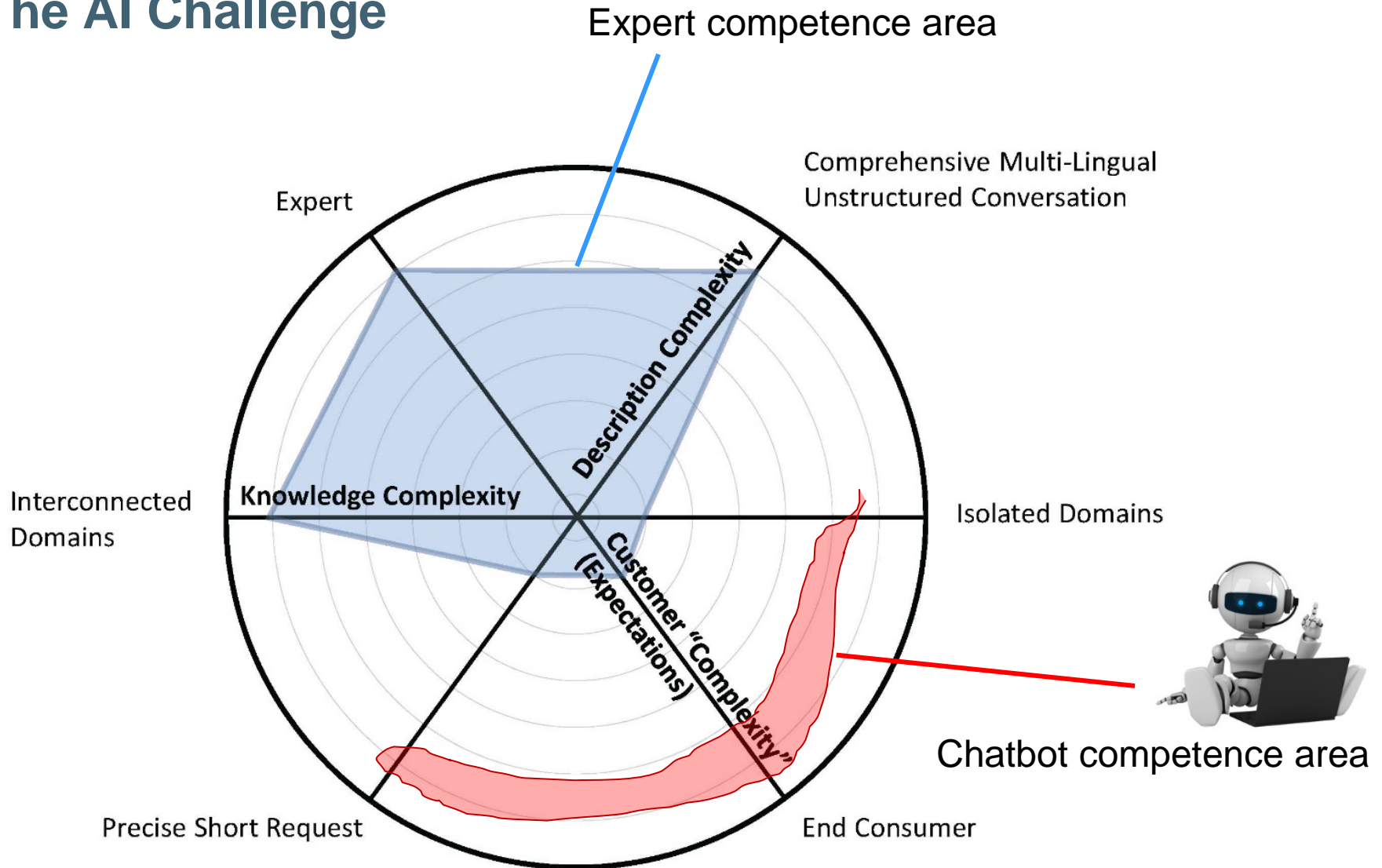
problem



re-opening rate

process cycle time

The AI Challenge



Tickets

- Over 80,000 from Fall 2015 to Spring 2017
 - submitted by humans or monitoring systems
 - in 2016: approx. 25,000 submitted by humans
- Often result from email conversations
- "Technoid" language
 - technical terms
 - grammar and spelling errors
 - multiple languages
 - sensitive information - *data protection matters!*
- Solved in a team effort - solution workflow

Example - Initiating Email (mostly in German)

```
Guten Tag
Ich möchte mit X1 auf die X2 in X3 zugreifen.
Unten die Anforderungen von der IT X3.
Ich bitte um Unterstützung beim Beantworten der Fragen und Umsetzung der Anforderungen.
Bitte rufen sie mich an.
Danke und freundliche Grüße
X4
-----
X AG
X4
mechanical engineer, dipl.Ing.HTL
O & M software engineer
Service
Xtrasse 00, Postfach 000
CH-0000 X
Phone++00(00) 000 00 00
Fax ++00 (00) 000 00 00
mail: ...@....com
web: www....com
```

- followed by over 200 lines of text in German, Finnish, English

Example - Closing Email (mostly in English)

From: X5 [mailto:....ch]
Sent: 26. huhtikuuta 2016 0:18
To: X6 [mailto:....fi]
Subject: X3 Internet Access to ROM

(1)

Dear X7,

(2)

we have no internet access anymore to the ROM PC.
Was there a change that X8 has direct access?
IP address in the ROM PC was 000.000.00.000
Our access from outside X9 was 00.000.000.0

Mit freundlichen Grüßen

(2)

X4

(5)

X AG
Xstrasse 00
0000 X
Schweiz
Tel. +00 00 000 00 00
Fax +00 00 000 00 00

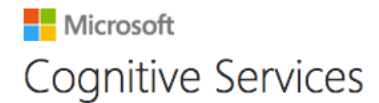
(3)

This email may contain confidential and/or legally
privileged information. If you have received it in
error, please notify the sender immediately and delete it
(together with any attachments) from your system without
using or disclosing its contents for any purposes or to any
other person. Many thanks for your co-operation.

(4)



Experiments with Cognitive Services



- Microsoft Text Analytics API
 - sentiment analysis, key phrase extraction
 - topic detection

- IBM Watson Natural Language Understanding
 - sentiment analysis, key word & entity extraction,
 - category detection

MS Key phrases / IBM Key words

	Complete Raw Text (312 lines)	Complete Extracted (78 lines)	German Raw / Extracted	English Raw / Extracted
MS TA Key phrases	-	long list of words	long list of words	long list of words
IBM NLU Key words	X3 Internet Access (0.95) mailto (0.81) H F (name) (0.70)	right IP config (0.94) adapter settings (0.92) remote connection (0.91)	41 44 277 (0.90) r@hz (0.83) s.r (name) (0.78) ----- Klopfwerksteuerung in X (0.97) Umsetzung der Anforderungen (0.80) rufen (0.54)	H F (name) (0.97) X AG (company) (0.81) ROM PC (0.77) ----- ROM (0.94) IP address (0.82) internet access (0.80)

➤ Only partially useful for texts in English

IBM NLU Categories and Concepts



Raw (312 lines)	Raw Extracted (78 lines)	German Raw / Extracted	English Raw / Extracted
javascript (0.63) router (0.48) vpn and remote access (0.44)	router (0.58) vpn and remote access (0.57) computer (0.27)	"categories: unsupported text language",	software (0.62) / (0.39) vpn and remote access (0.53) / (0.63) computer (0.47) / 0.58)
IP address (0.95) Subnetwork (0.64) Dynamic Host Configuration Protocol (0.57)	IP address (0.97) Dynamic Host Configuration Protocol (0.78) Subnetwork (0.78)	"concepts: unsupported text language"	Internet (0.95) IP address (0.94) Internet Protocol (0.65) ----- IP address (0.98) Internet (0.93) Internet Protocol (0.70)

- Ontology-based information extraction works better, but
 - is it specific enough?
 - will it carry over to other application domains?

Sentiment Analysis

- 312 text lines including empty lines
- Microsoft TA rejects full text because of size (10240 bytes)
 - score between 0 and 1 (0.5 neutral)
- IBM NLU set to English/German
 - score between -1 and 1 (0 neutral)

	Full (312 lines)	Full Extracted (78 lines)	German Full/Extracted	English Full/Extracted
MS TA Sentiments	-	0.97	0.73 / 0.50	0.99 / 0.21
IBM Sentiments	0.01	-0.31	0.3 / 0.0	0.01 / -0.74

➤ Better not used on our texts

IBM Sentiment Analysis

Scale [-1 (negative), +1 (positive)] - 0 neutral

Example 1:

-0.769482

Frau M hat Probleme mit dem Citrix Receiver.

Herr S hat diesen zurück gesetzt, leider hat das nichts gebracht.

Darauf hin hat er diesen neu installiert und eingerichtet, beim auswählen des Kontos kommt die Fehlermeldung dass das Konto bereits hinzugefügt wurde.

Example 2:

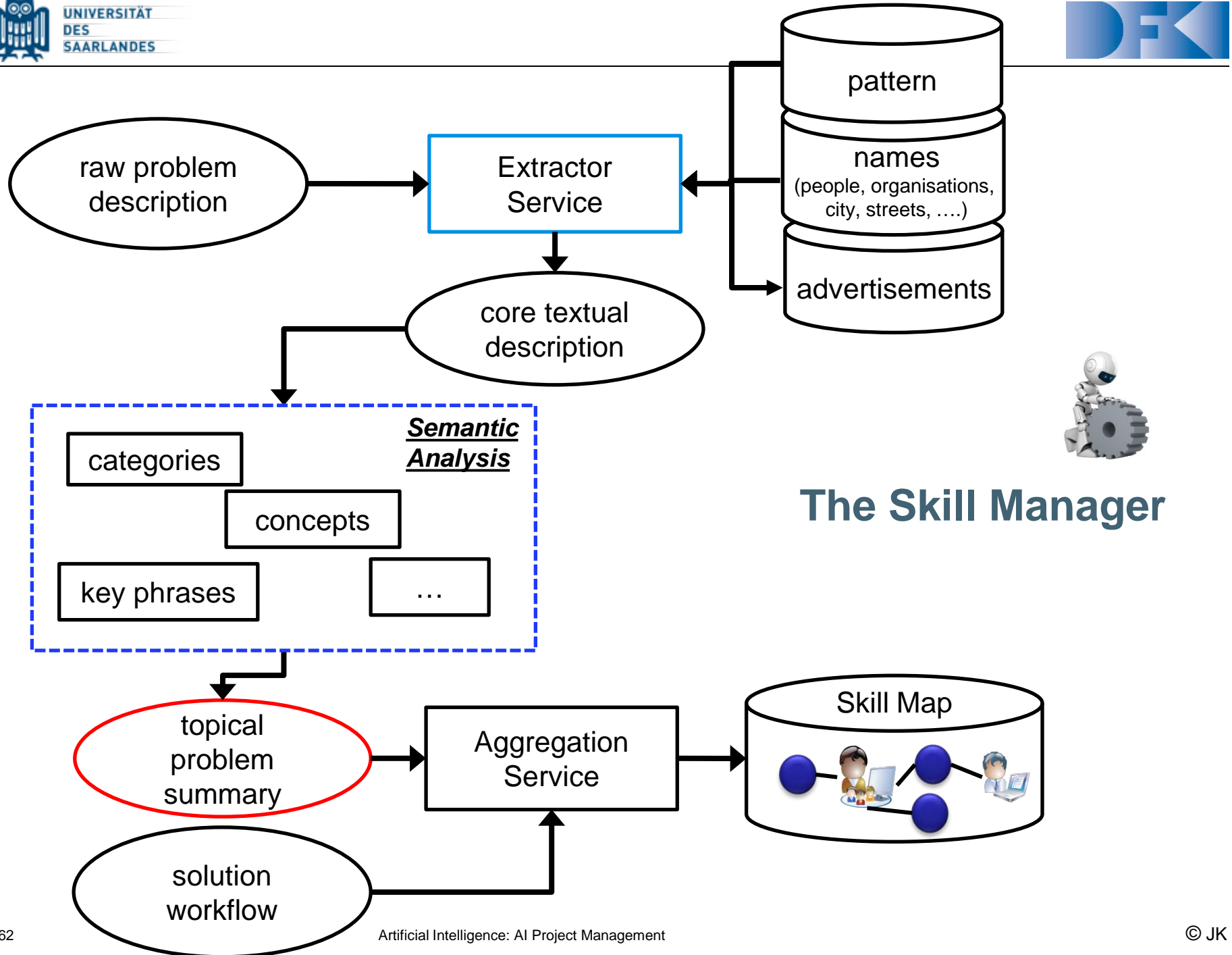
+ 0.848139

Hallo Zusammen

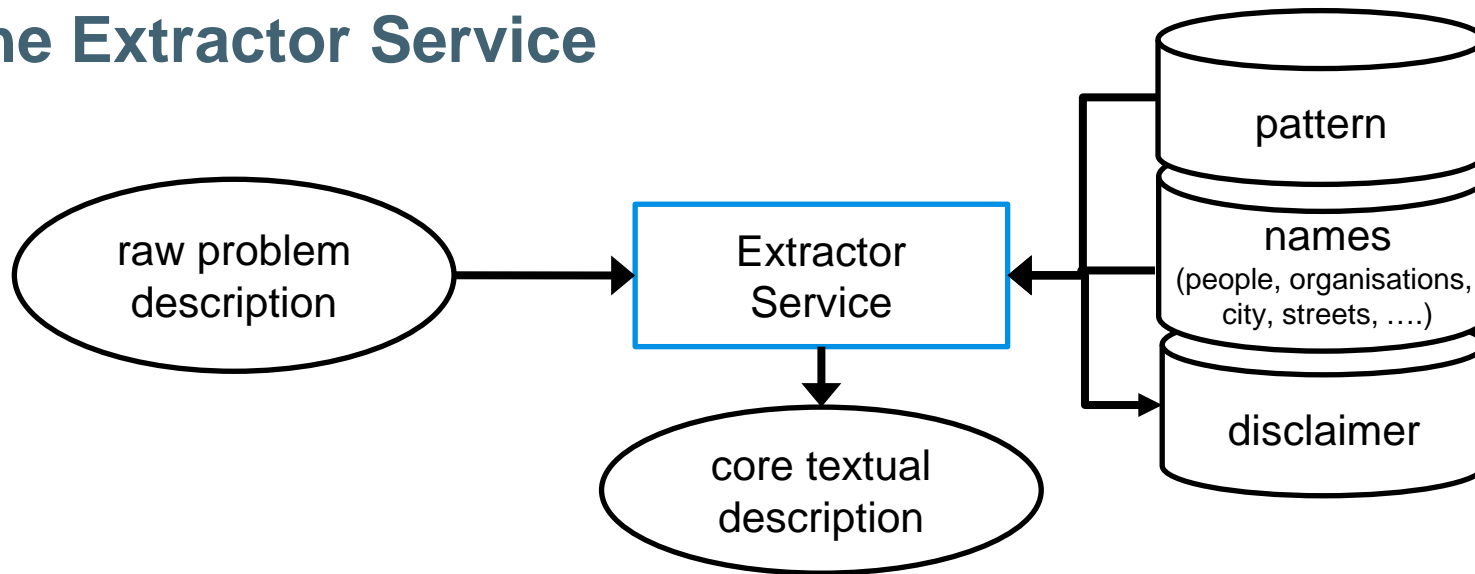
Die Mitarbeiterin G kann die E-Mails aus dem POS-Eingang (POS=E-Mails für den Vorverkauf) weder löschen noch verschieben.

Könnt ihr bitte die Rechte erteilen und mich informieren wann es erledigt ist.

Danke und Gruss S

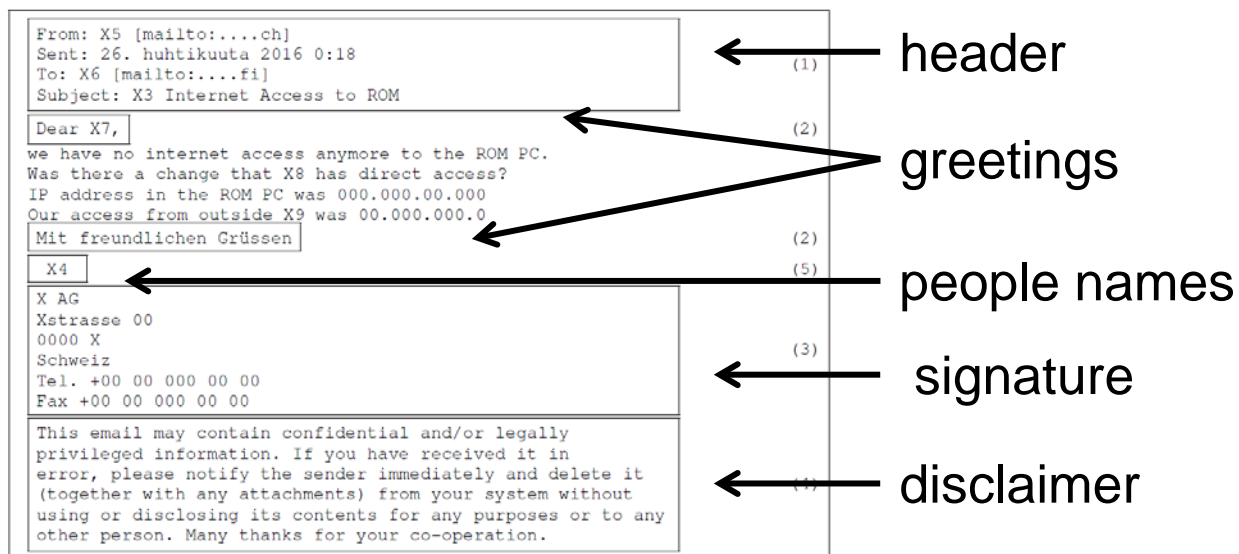


The Extractor Service



- de Carvalho/Cohen: Learning to extract signature and reply lines from email [CEAS, 2004]
 - Sequence of lines approach
 - Pattern-based feature vector for each line
 - Used to train an ML classifier
- + Matching of multi-language patterns
- + Arbitrary conversations

Pattern-based Textline Features



*in arbitrary order
and multiple
languages*

pattern	regular expression
salutation (g)	(\s \A) ((S s)ehr geehrt (H h)err(en)? (F f)rau (D d)amen Liebe(r s) (L l)ieber? (L l)iebster? (H h)allo(H h)ey G g)rezi (H h) (I i) (M m)orgen? (G g)ue?ten? ((Tag Abend Morgen? Obig) (H h)oi), ?.?(\s \Z)
greeting (g)	\s \A ((G g)r(ue u)(ss)e?n? (A)lles ((G g)ute (G g)ueti) (H h)erzlich Alles (L l)ieb(e i) [D d]anke? (S s)ali (V v)ielen?), ?.?(\s \Z)
salutation (e)	\s \A ((D d)ear (D d)earest (H h)ello (H h)ey (M m)y (D d)ear), ?.?(\s \Z)
greeting (e)	\s \A ((R r)egards? (T t)hanks (C c)heers (G g)rateful (S s)incerely), ?.?(\s \Z)

Number of Patterns

10 greetings

16 headers

113 signatures

Supervised Learning

90 Patterns + 1 Annotator Studio + 3 Assistants + 1 Day =
900 Tickets

From: X5 [mailto:....ch]
Sent: 26. huhtikuuta 2016 0:18
To: X6 [mailto:....fi]
Subject: X3 Internet Access to ROM

(1)

Dear X7,

(2)

we have no internet access anymore to the ROM PC.
Was there a change that X8 has direct access?
IP address in the ROM PC was 000.000.00.000
Our access from outside X9 was 00.000.000.0

Mit freundlichen Grüßen

(2)

X4

(5)

X AG
Xstrasse 00
0000 X
Schweiz
Tel. +00 00 000 00 00
Fax +00 00 000 00 00

(3)

This email may contain confidential and/or legally
privileged information. If you have received it in
error, please notify the sender immediately and delete it
(together with any attachments) from your system without
using or disclosing its contents for any purposes or to any
other person. Many thanks for your co-operation.

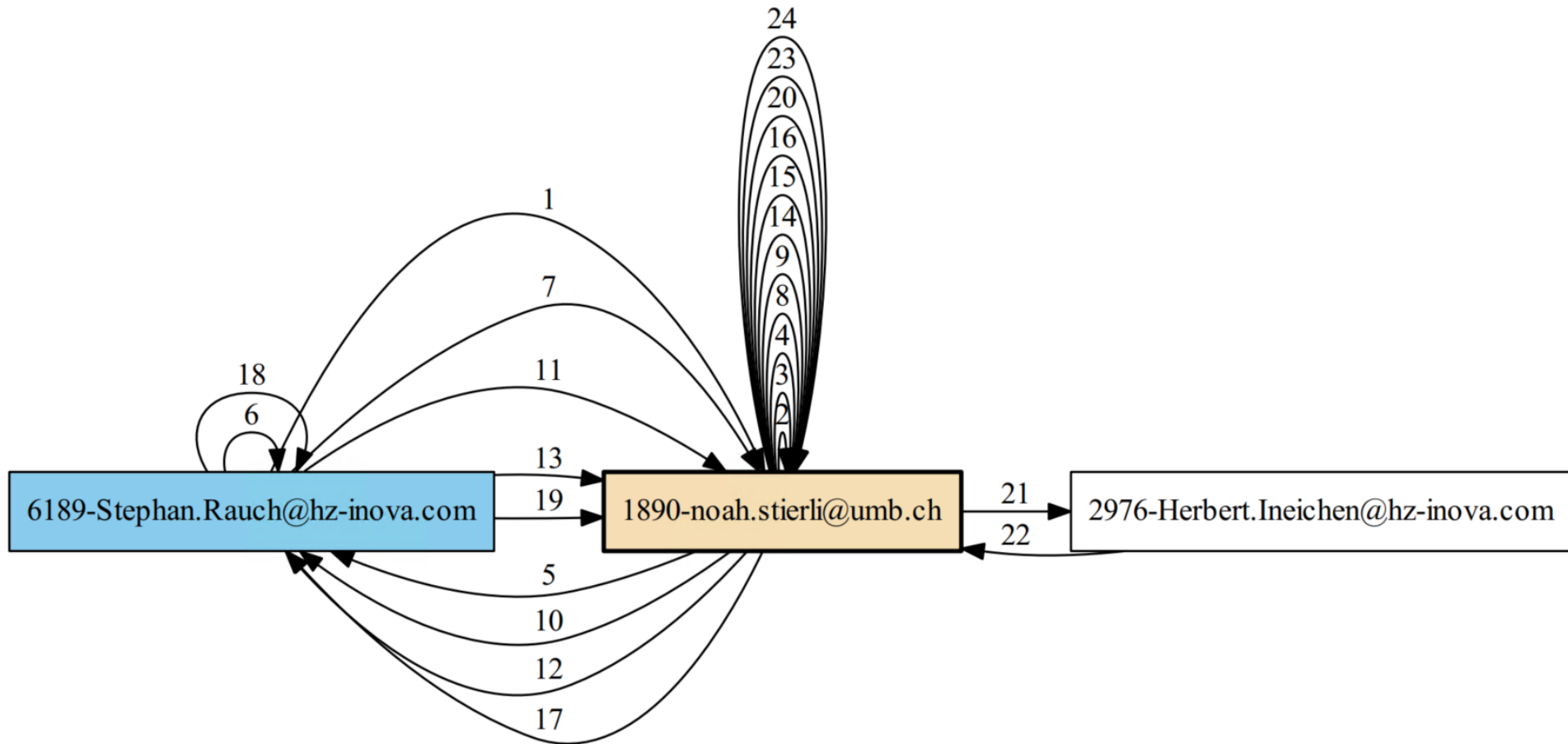
(4)

Threshold-based Classifier vs. Trained Classifiers

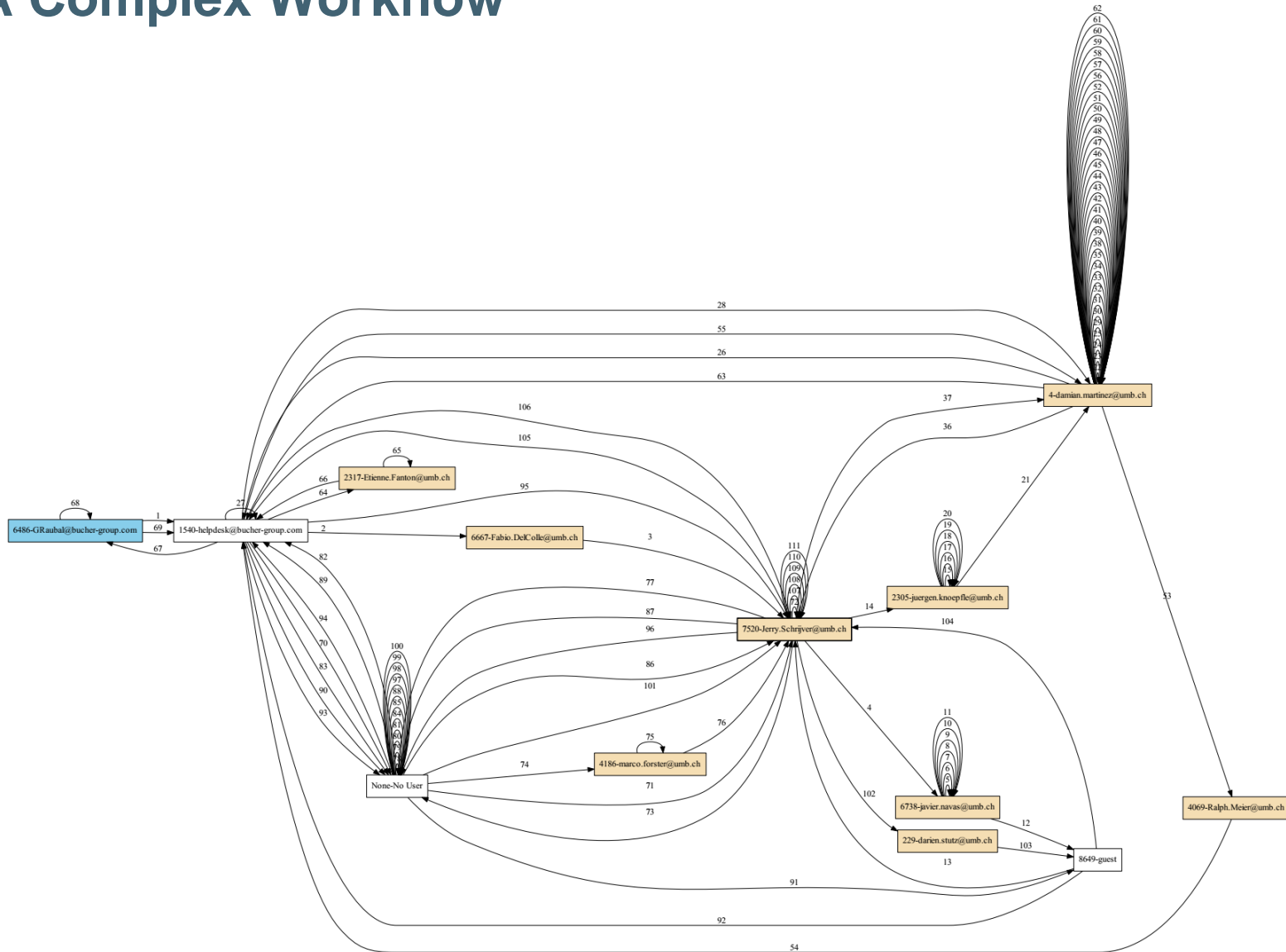
Category	No. of lines	FP	FN	TP	TN	Accuracy (%)	$F_{0.5}$ (%)
header	2065	13	198	1867	24210	99.19	97.39
greeting	1853	150	523	1330	24285	97.44	85.55
signature	8120	3696	2028	6092	14472	78.22	64.44
disclaimer	1167	199	868	299	24922	95.94	47.33
name	585	987	254	331	24716	95.28	28.26
problem description	12498	2551	3725	8773	11239	76.13	75.90

Feature Vector	Learner	FP	FN	TP	TN	Accuracy (%)	$F_{0.5}$ (%)
signature only	SVM	237	588	1052	3381	84.31	77.40
signature only	AdaBoost	216	613	1027	3402	84.23	77.66
signature only	RF	142	489	1151	3476	87.99	84.48
sign. + header	SVM	220	573	1067	3398	84.91	78.59
sign. + header	AdaBoost	216	552	1088	3402	85.39	79.35
sign. + header	RF	155	444	1196	3463	88.61	84.90
all features	SVM	215	553	1087	3403	85.39	79.37
all features	AdaBoost	219	527	1113	3399	85.81	79.87
all features	RF	148	422	1218	3470	89.16	85.73

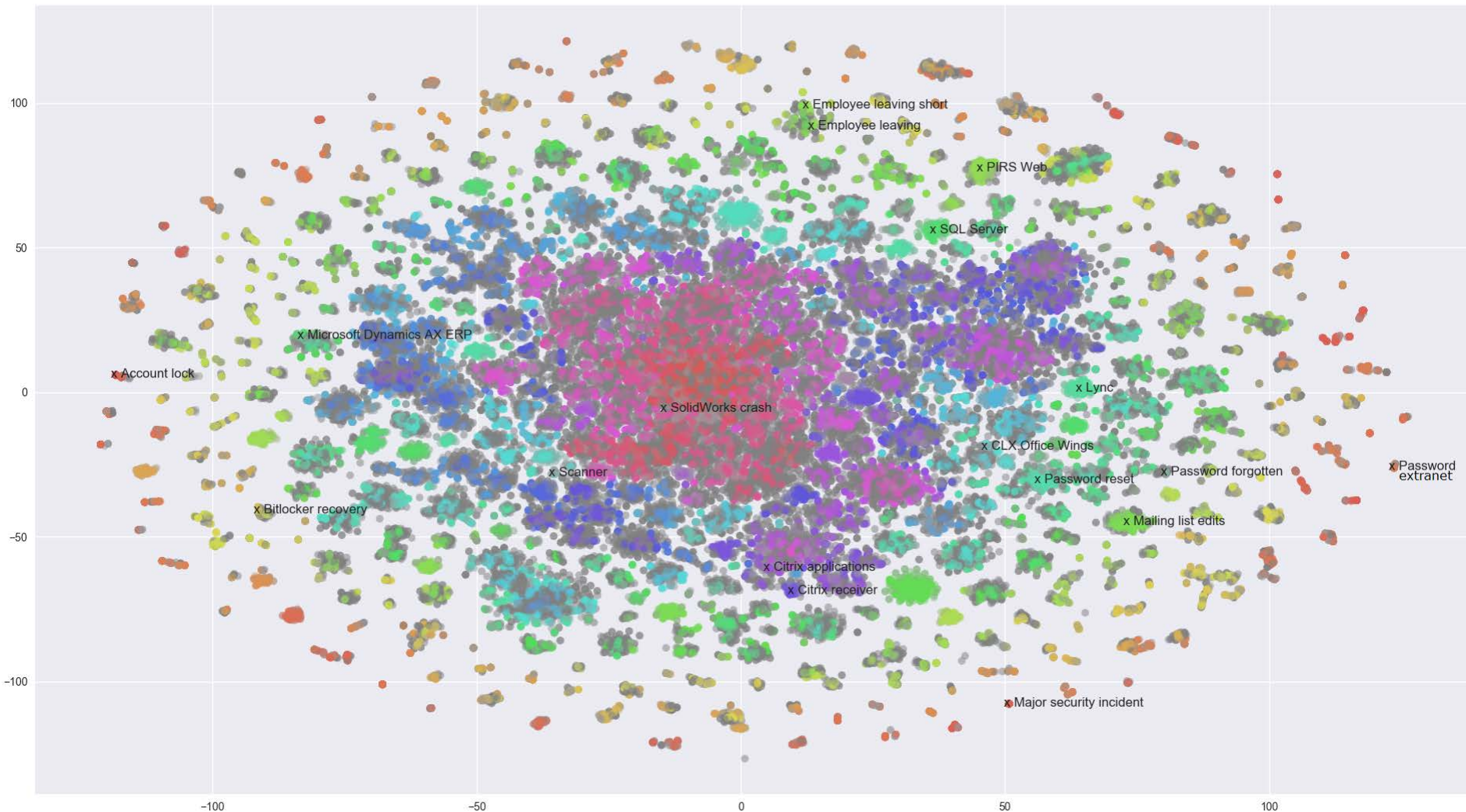
Analyzing Solution Workflows



A Complex Workflow



Unsupervised Learning / Ticket Clustering with HDBSCAN



What Worked and Did not Work?

Worked:

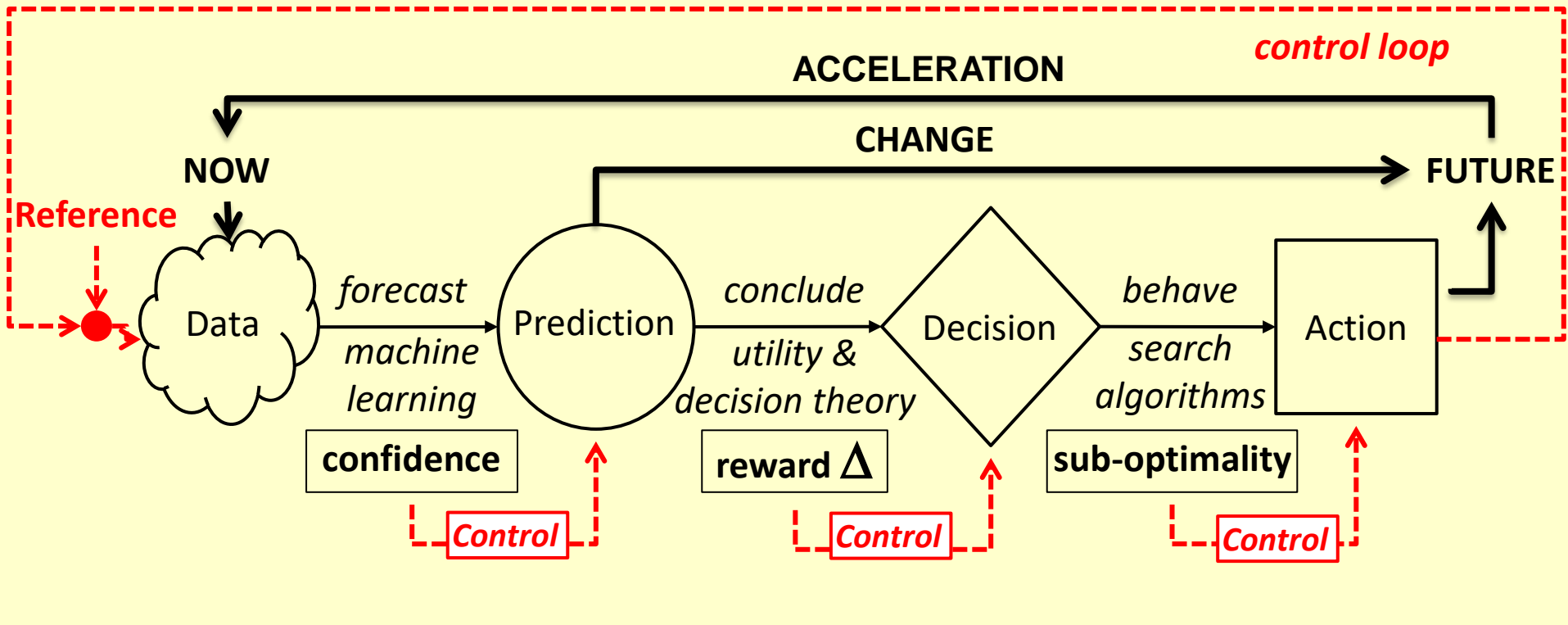
- Removing problem-irrelevant information from tickets
- Finding similar tickets by unsupervised learning (clustering)
- Find best expert(s) for problem from workflow analysis

Not Worked:

- Text summary and keyphrase extraction (no out-of-the box solution, technically feasible, but not viable)
- Reusing ticket solutions (not documented)
- Integration into 3rd party ticketing system (too much effort)
- Definition of business model

Lessons Learned

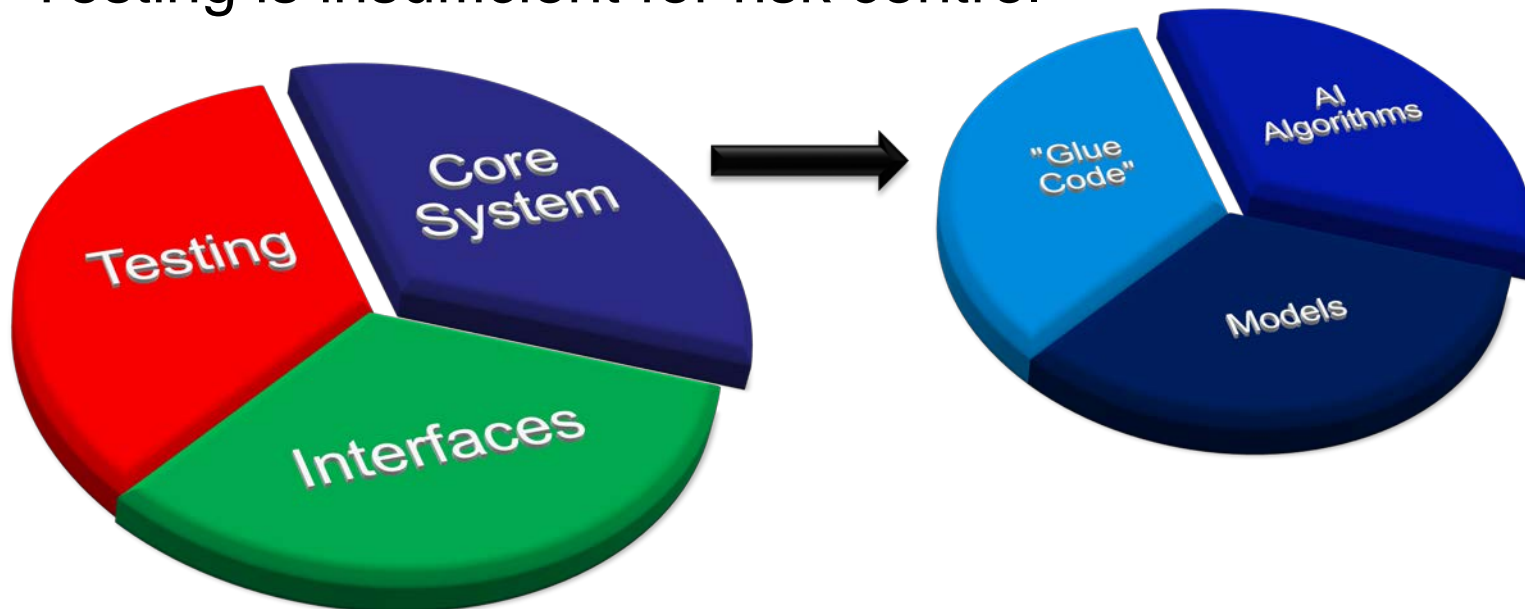
Controlling the Risk



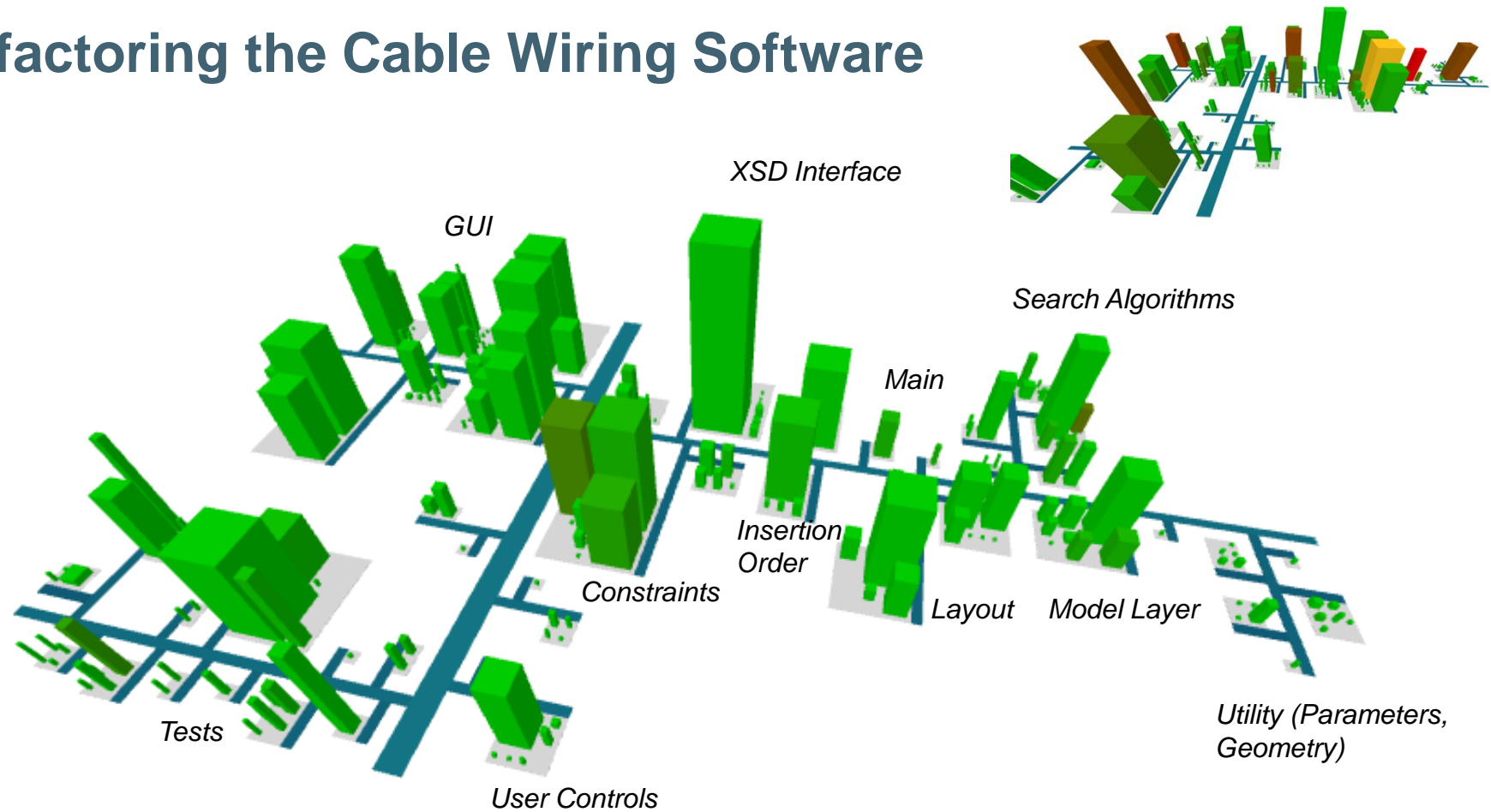
- Provide reference behavior if possible
- Manage deviations and foresee escalation mechanisms
- Focus on **system stability** by design
 - over all information, decision, action layers & short-/long-term horizons

AI Projects are Complex Software Projects

- Scope and context matter more than ever
- Requirements engineering + knowledge engineering
- SYSTEM QUALITIES influenced by AI approach
- Simplification and refactoring as ongoing challenges
- Testing is insufficient for risk control



Refactoring the Cable Wiring Software



Footprint: Complexity

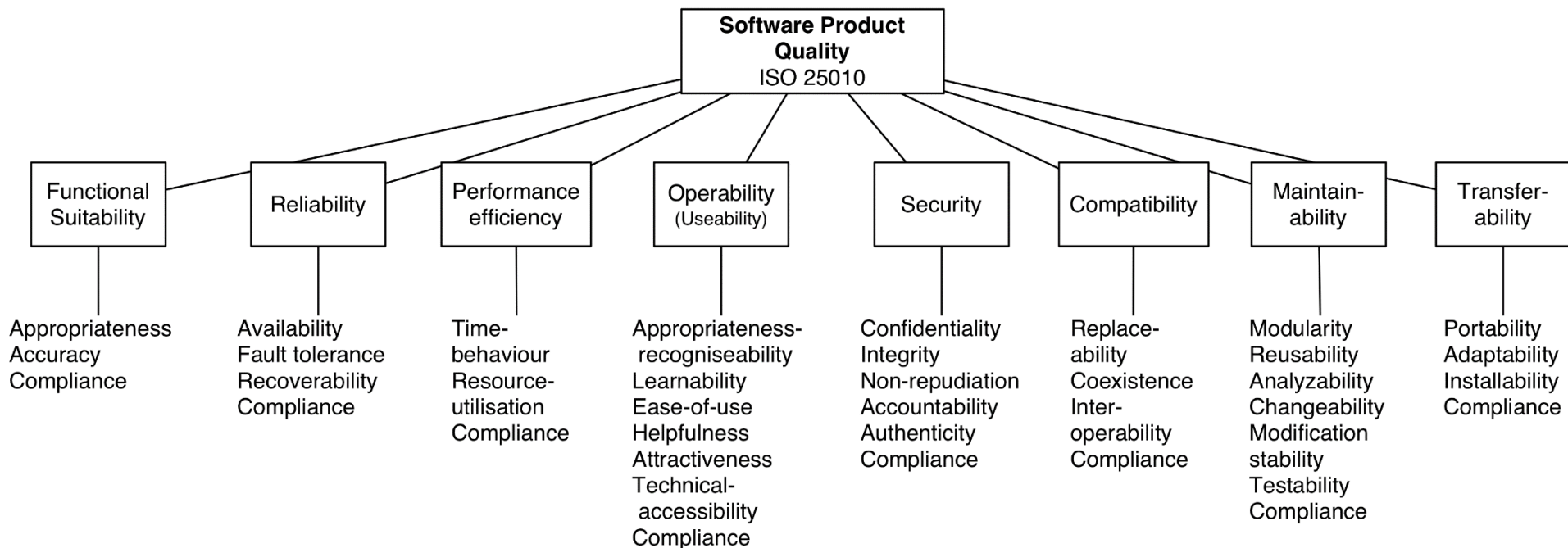
Height: Lines of Code

Color:

Sonarcube Visualization

AI requires Re-Interpretation of Quality Characteristics in ISO/IEC 25010:2011 (Reviewed and confirmed in 2017)

Systems and software engineering -- Systems and software Quality Requirements and Evaluation (SQuaRE) -- System and software quality models



➤ Lecture in Winter Semester: [Architectural Thinking for Intelligent Systems](#)

<https://faq.arc42.org/images/faq/C-Sections/ISO-25010-EN.png>

Summary and Lessons Learned

- Preparing the Project
 - Legal clarity first
 - Manage heterogeneous teams
 - Achieve viable business model
 - Secure critical resources
 - Estimate efforts
- Running the Project
 - Evaluate technologies
 - Master true agility
 - Generate labeled data
 - Revisit algorithm decisions
 - Manage software complexity
 - Apply architectural thinking & manage decisions
- Finishing the Project
 - Transfer solution to market
 - Manage the data pipeline
 - Plan for and adopt technology evolutions

Useful Thoughts about Machine Learning

10 Things Everyone Should Know About Machine Learning

<https://hackernoon.com/10-things-everyone-should-know-about-machine-learning-d2c79ec43201>

A Few Useful Things to Know about Machine Learning

<https://homes.cs.washington.edu/~pedrod/papers/cacm12.pdf>

Things I wish we had known before we started our first Machine Learning project

<https://medium.com/infinity-aka-aseem/things-we-wish-we-had-known-before-we-started-our-first-machine-learning-project-336d1d6f2184>

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