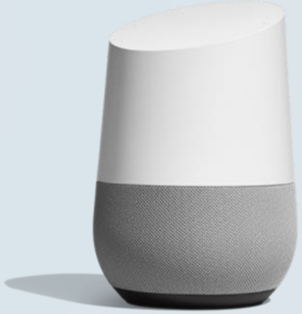
How to determine the success of Smart Products?
A Machine Learning Approach

Louis Püschel

WAS IST EIN SMARTES PRODUKT?



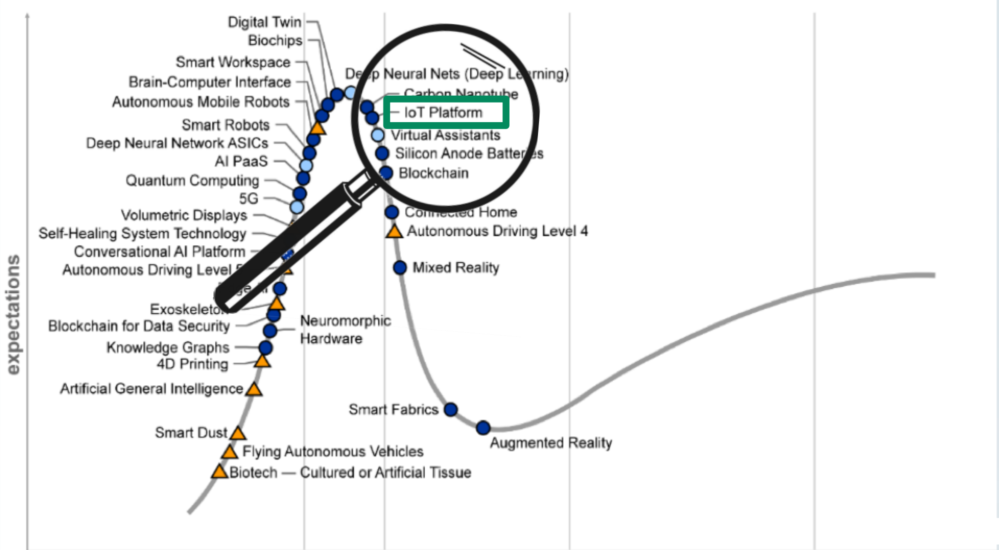
“The Internet of Things (IoT) refers to the connectivity of physical objects, equipped with sensors and actuators, to the Internet via data communication technology, enabling interaction with and/or among these objects.“

MOTIVATION

Internet der Dinge:
Wertschöpfung bis 2022 $14,4 Billionen

Anzahl verbundener Geräte

2015	2025
ca. 15,4 Milliarden	ca. 75,4 Milliarden



Internet der Dinge im Gartner Hype Cycle 2018

Smart City

Exemplarisch

Husqvarna, Google, BOSCH, amazon.com

Health, Well-Being

Exemplarisch

PHILIPS, CliniCloud, fitbit, GARMIN, SIEMENS, Microsoft

Industrial

Exemplarisch

ROLLS ROYCE, CATERPILLAR, HILTI, BOSCH, AIRBUS

PROJEKT-FRAGE?

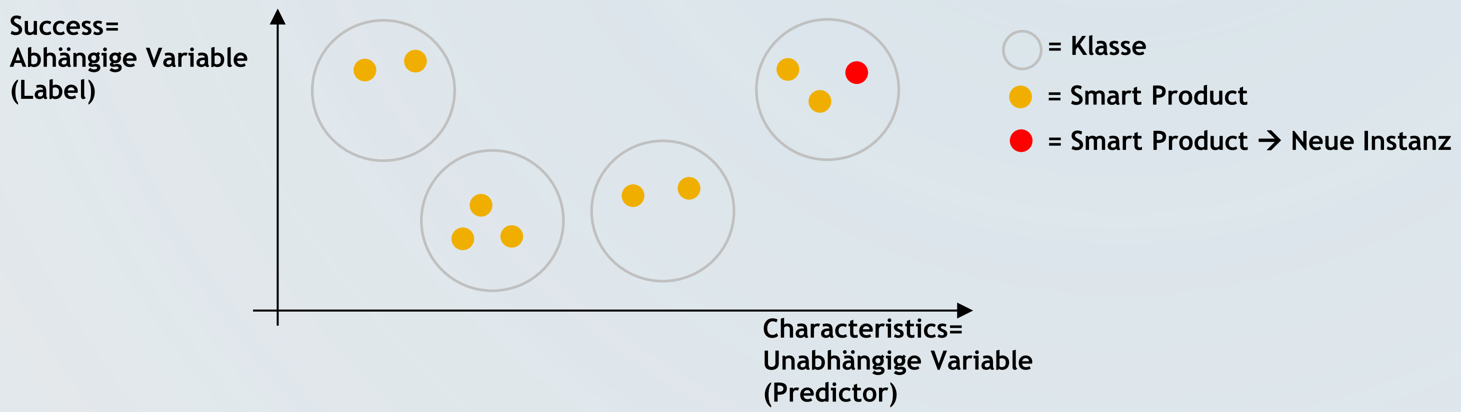
Welche Smarten Produkte sind besonders erfolgreich?

Um welches Produkt-Typen handelt es sich?

Wie kann Unternehmen eine Entscheidungshilfe an die Hand gegeben werden?

✓ Prognose des Erfolgs mit Hilfe von Machine Learning

PROGNOSE MITTELS SUPPORT VECTOR MACHINE



Erklärung / These

- SVM **trainiert aufgrund** von **Characteristics** und **Markterfolg** (Success) der Smarten Produkte
- **Je nach** dem welche **Characteristics** das Smarte Produkte hat, wird es einen **bestimmten Erfolg** haben
- **Erfolg** ergibt sich aus **Google-Suchanfragen**
- **Anwendung** SVM auf gänzlich **neues Objekt/Instanz**

WAS BRAUCHEN WIR DAZU? DIE VORARBEITEN!

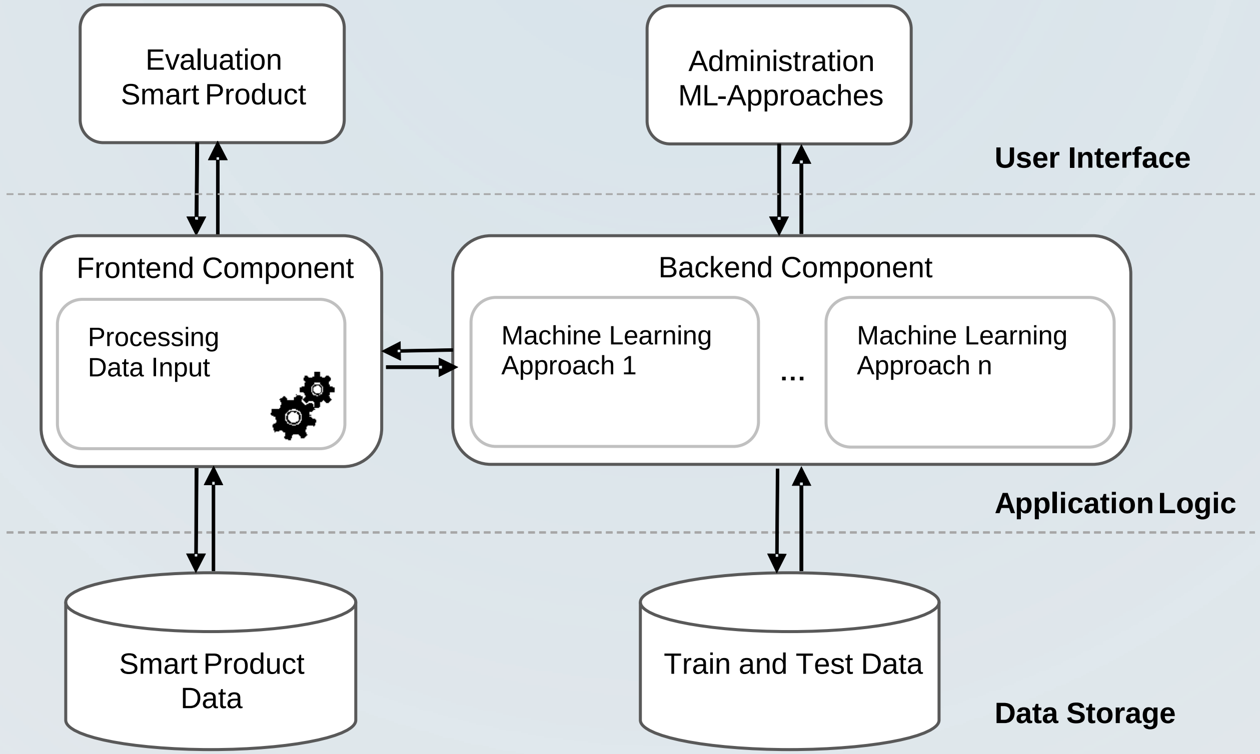
Taxonomie
Allgemeingültige Beschreibung Smarter Produkt

Datensatz
Ca. 200 klassifizierte Smarte Produkte, deren Erfolgskennzahlen und Typ-Zuordnung

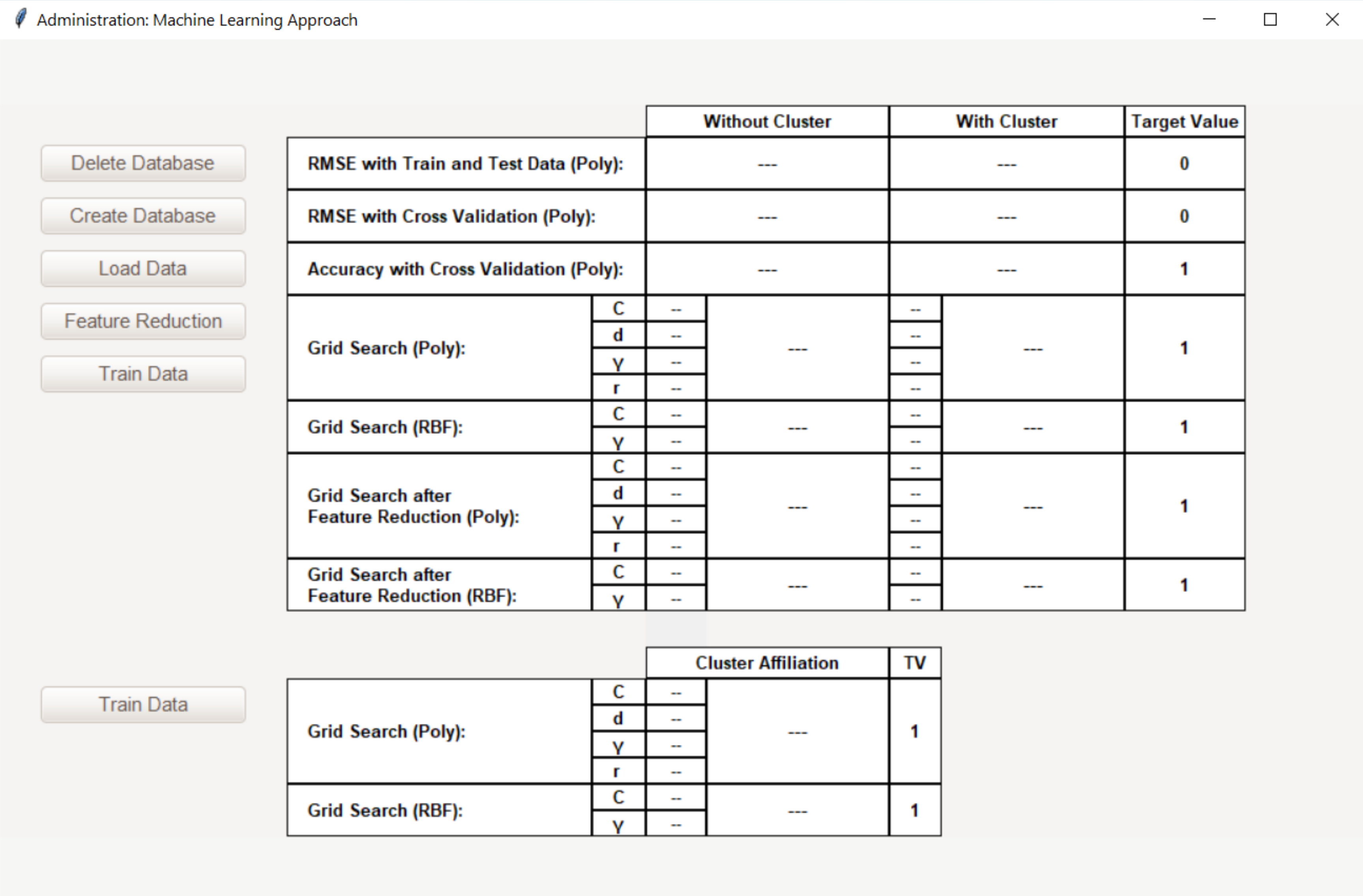
	Dimension	Characteristics			
Service	Ecosystem Integration	None	Proprietary	Open	
Service	Value Proposition	Thing-centric	Service-centric		
Service	Offline Functionality	None	Limited		
Data	Data Usage	Transactional	Analytical (basic)	Analytical (extended)	
Data	Data Source	Thing State	Thing Context	Thing Usage	Cloud
Interaction	Interaction Partner	User(s)	Business(es)	Thing(s)	
Interaction	Interaction Multiplicity	One-to-one	One-to-many		
Interaction	Interaction Direction	Unidirectional	Bi-directional		
Thing	Autonomy	None	Self-Controlled	Self-Learning	
Thing	Acting Capabilities	Own	Intermediary		
Thing	Sensing Capabilities	Lean	Rich		

	A	B	C	D	E	F	G	H
1	sensing	acting_own	acting_inte	autonomy	direction	multiplicity	partner_use	partner_b
2	0.00	0.50	0.50	0.50	0.00	1.00	0.33	0.00
3	0.00	0.00	0.50	0.00	0.00	0.00	0.33	0.00
4	0.00	0.00	0.50	0.00	0.00	1.00	0.33	0.33
5	0.00	0.50	0.00	0.00	0.00	1.00	0.33	0.00
6	1.00	0.50	0.50	0.50	1.00	0.00	0.33	0.00
7	0.00	0.50	0.50	1.00	1.00	1.00	0.33	0.00
8	0.00	0.50	0.50	0.00	0.00	0.00	0.33	0.00
9	1.00	0.50	0.50	0.00	1.00	0.00	0.33	0.00
10	1.00	0.50	0.50	0.00	1.00	1.00	0.33	0.00
11	0.00	0.00	0.50	0.50	1.00	1.00	0.33	0.00
12	0.00	0.50	0.50	0.50	0.00	1.00	0.33	0.00
13	1.00	0.00	0.50	0.50	0.00	1.00	0.33	0.00
14	1.00	0.50	0.50	0.50	0.00	0.00	0.33	0.00
15	0.00	0.00	0.50	0.00	0.00	0.00	0.33	0.00
16	0.00	0.00	0.50	0.00	0.00	0.00	0.33	0.00
17	0.00	0.50	0.50	0.00	1.00	1.00	0.33	0.00
18	0.00	0.50	0.50	0.50	0.00	1.00	0.33	0.00
19	0.00	0.50	0.50	0.00	1.00	1.00	0.33	0.00
20	0.00	0.00	0.50	1.00	1.00	0.00	0.33	0.00
21	1.00	0.00	0.50	0.00	0.00	1.00	0.33	0.00
22	1.00	0.00	0.50	0.00	0.00	0.00	0.33	0.00

UMSETZUNG: DREISCHICHTEN ARCHITEKTUR



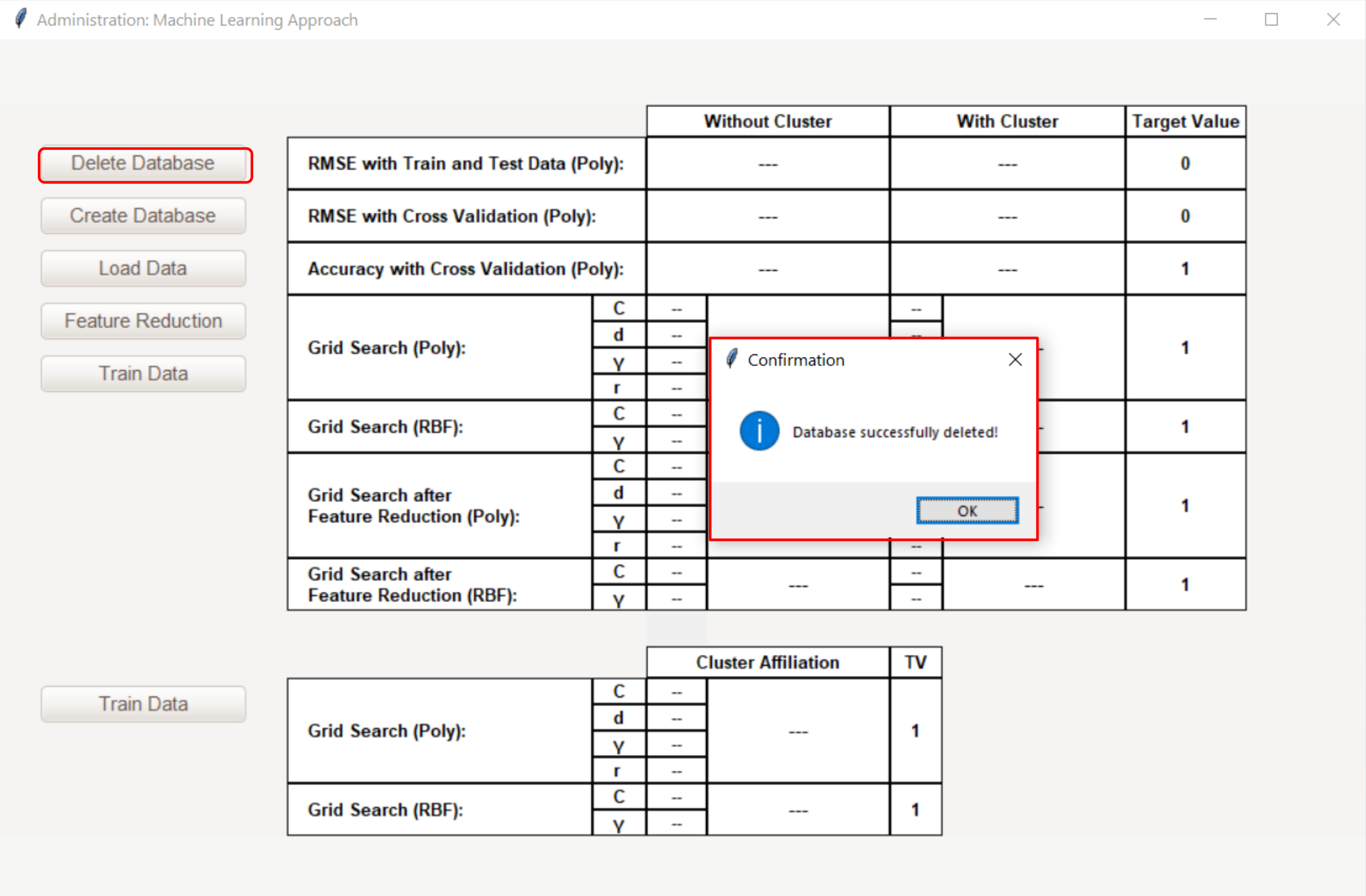
UMSETZUNG: BACKEND USER INTERFACE



		Without Cluster		With Cluster		Target Value
RMSE with Train and Test Data (Poly):		---		---		0
RMSE with Cross Validation (Poly):		---		---		0
Accuracy with Cross Validation (Poly):		---		---		1
Grid Search (Poly):	C	--	---	--	---	1
	d	--		--		
	γ	--		--		
	r	--		--		
Grid Search (RBF):	C	--	---	--	---	1
	γ	--		--		
Grid Search after Feature Reduction (Poly):	C	--	---	--	---	1
	d	--		--		
	γ	--		--		
	r	--		--		
Grid Search after Feature Reduction (RBF):	C	--	---	--	---	1
	γ	--		--		

		Cluster Affiliation		TV
Grid Search (Poly):	C	--	---	1
	d	--		
	γ	--		
	r	--		
Grid Search (RBF):	C	--	---	1
	γ	--		

UMSETZUNG: BACKEND USER INTERFACE



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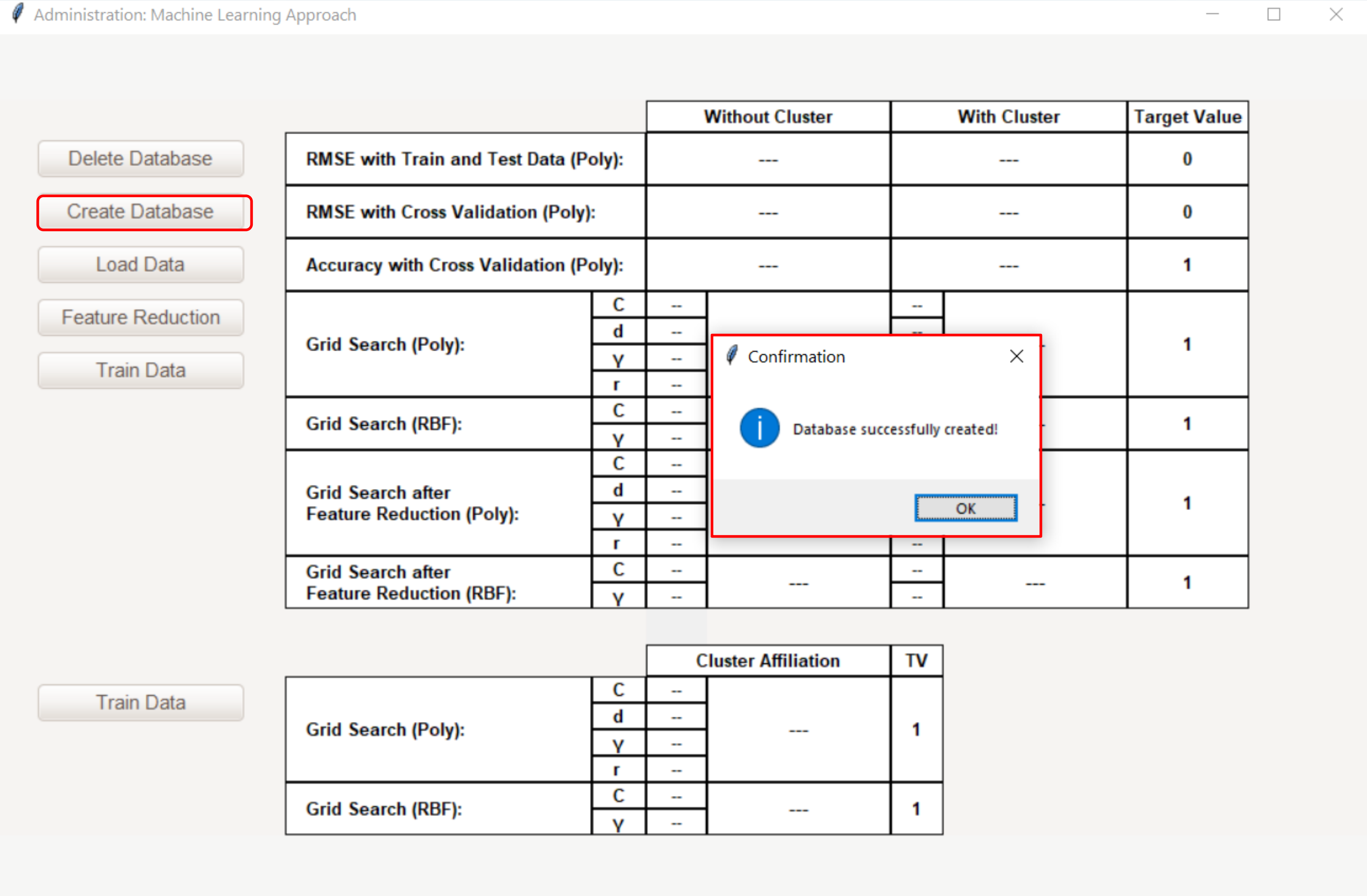

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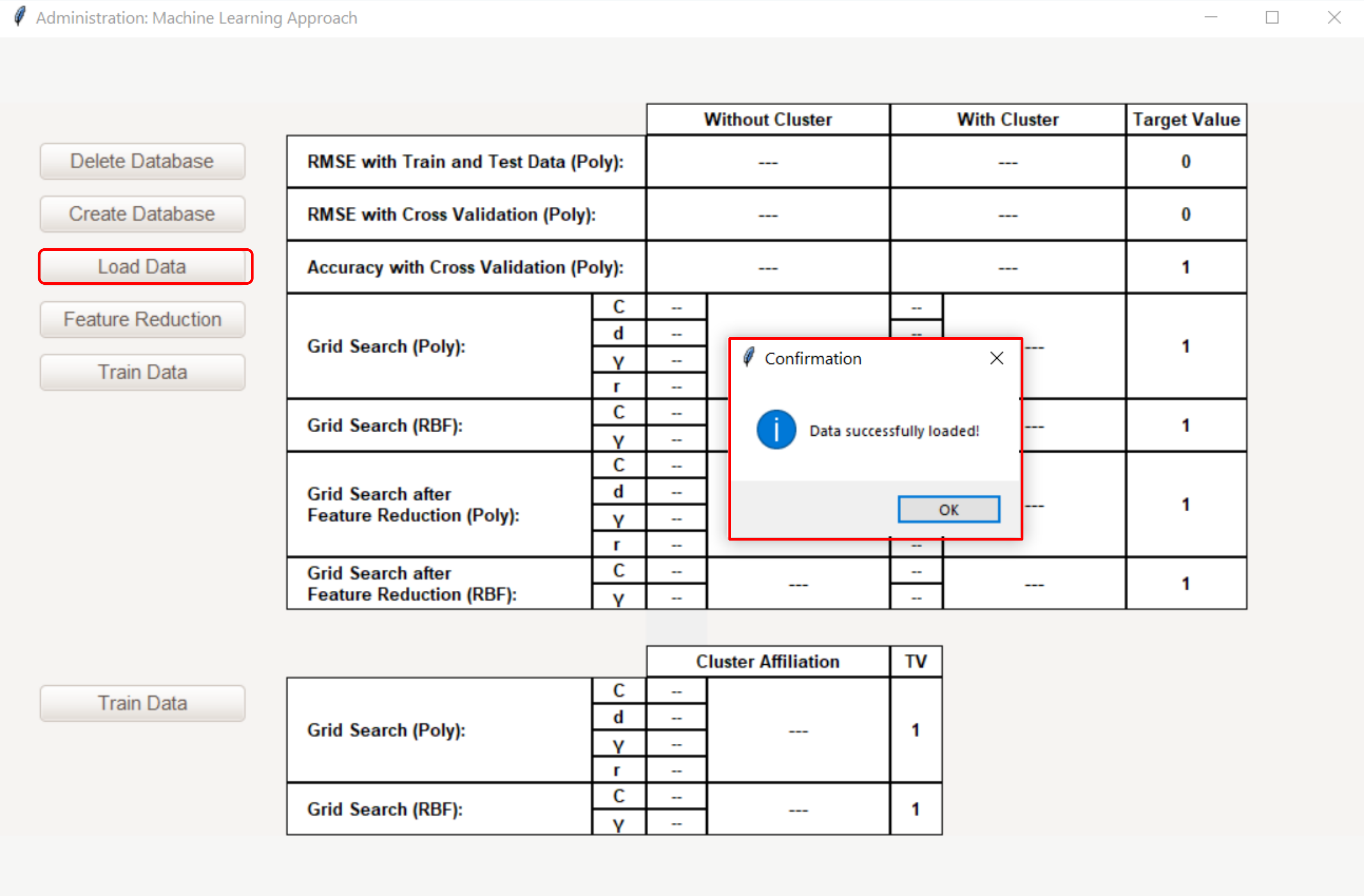

UMSETZUNG: BACKEND USER INTERFACE

Administration: Machine Learning Approach

Delete Database

Create Database

Load Data

Feature Reduction

Train Data

	Without Cluster	With Cluster	Target Value
RMSE with Train and Test Data (Poly):	---	---	0
RMSE with Cross Validation (Poly):	---	---	0
Accuracy with Cross Validation (Poly):	---	---	1
C --		--	
Grid Search after Feature Reduction (RBF): C --, γ --	---	--, -- / ---	1

Results Feature Reduction: Principal Component Analysis

Auszug

Nr. Component	Variance	sensing	acting_own	acting_inter	autonomy	direction	multiplicity	partner_user	partner_business	partner_thing	source_state	so
1	**0.41**	0.12	0.01	0.0	0.08	0.06	0.02	-0.0	0.01	0.01	-0.01	
2	**0.17**	-0.33	-0.01	0.0	-0.18	-0.19	-0.39	-0.0	-0.02	-0.09	0.03	
3	**0.12**	0.08	0.27	-0.02	0.18	0.55	0.36	-0.0	0.01	0.08	0.02	
4	**0.09**	0.31	0.03	0.01	0.17	0.53	-0.49	0.0	0.01	-0.11	-0.04	
5	**0.06**	0.76	-0.02	0.0	-0.03	-0.47	0.19	-0.01	0.04	-0.03	-0.01	

Train Data

			Cluster Affiliation	TV
Grid Search (Poly):	C	--	---	1
	d	--		
	γ	--		
	r	--		
Grid Search (RBF):	C	--	---	1
	γ	--		

UMSETZUNG: BACKEND USER INTERFACE

Administration: Machine Learning Approach

Niedrige Güte aufgrund unzureichender Datenbasis

- Delete Database
- Create Database
- Load Data
- Feature Reduction
- Train Data

		Without Cluster		With Cluster		
RMSE with Train and Test Data (Poly):		1.51		1.51		0
RMSE with Cross Validation (Poly):		1.38		1.36		0
Accuracy with Cross Validation (Poly):		0.32		0.3		1
Grid Search (Poly):	C	24	0.42	24	0.4	1
	d	1		1		
	γ	5		4		
	r	2		2		
Grid Search (RBF):	C	1	0.38	2	0.39	1
	γ	35		85		
Grid Search after Feature Reduction (Poly):	C	20	0.41	18	0.35	1
	d	3		1		
	γ	5		3		
	r	0		0		
Grid Search after Feature Reduction (RBF):	C	200	0.39	6	0.32	1
	γ	65		100		

- Train Data

		Cluster Affiliation		TV
Grid Search (Poly):	C	--	---	1
	d	--		
	γ	--		
	r	--		
Grid Search (RBF):	C	--	---	1
	γ	--		

UMSETZUNG: BACKEND USER INTERFACE

Administration: Machine Learning Approach

Delete Database

Create Database

Load Data

Feature Reduction

Train Data

		Without Cluster		With Cluster		Target Value
RMSE with Train and Test Data (Poly):		---		---		0
RMSE with Cross Validation (Poly):		---		---		0
Accuracy with Cross Validation (Poly):		---		---		1
Grid Search (Poly):	C	--	---	--	---	1
	d	--		--		
	γ	--		--		
	r	--		--		
Grid Search (RBF):	C	--	---	--	---	1
	γ	--		--		
Grid Search after Feature Reduction (Poly):	C	--	---	--	---	1
	d	--		--		
	γ	--		--		
	r	--		--		
Grid Search after Feature Reduction (RBF):	C	--	---	--	---	1
	γ	--		--		

Train Data

		Cluster Affiliation		
Grid Search (Poly):	C	2	0.7	1
	d	1		
	γ	4		
	r	0		
Grid Search (RBF):	C	1	0.73	1
	γ	1		

Güte gut bis sehr gut

UMSETZUNG: FRONTEND USER INTERFACE

Smart Product Evaluation

Service	Ecosystem Integration	None	Proprietary	Open		ME
	Value Proposition	Thing-Centric	Service-Centric			ME
	Offline Functionality	None	Limited			ME
Data	Data Usage	Transactional	Analytical (basic)	Analytical (extended)		ME
	Data Source	Thing State	Thing Context	Thing Usage	Cloud	Non E
Interaction	Interaction Partner	User	Business	Thing		Non E
	Interaction Multiplicty	One-To-One	One-To-Many			ME
	Interaction Direction	Uni-Directional	Bi-Directional			ME
Thing	Autonomy	None	Self-Controlled	Self-Learning		ME
	Acting Capabilities	Own	Intermediary			Non E
	Sensing Capabilities	Lean	Rich			ME

Submit

SHOW CASE AM BEISPIEL „FITBIT“

	Dimension	Characteristics			
Service	Ecosystem Integration	None	Proprietary	Open	
	Value Proposition	Thing-centric	Service-centric		
	Offline Functionality	None	Limited		
Data	Data Usage	Transactional	Analytical (basic)	Analytical (extended)	
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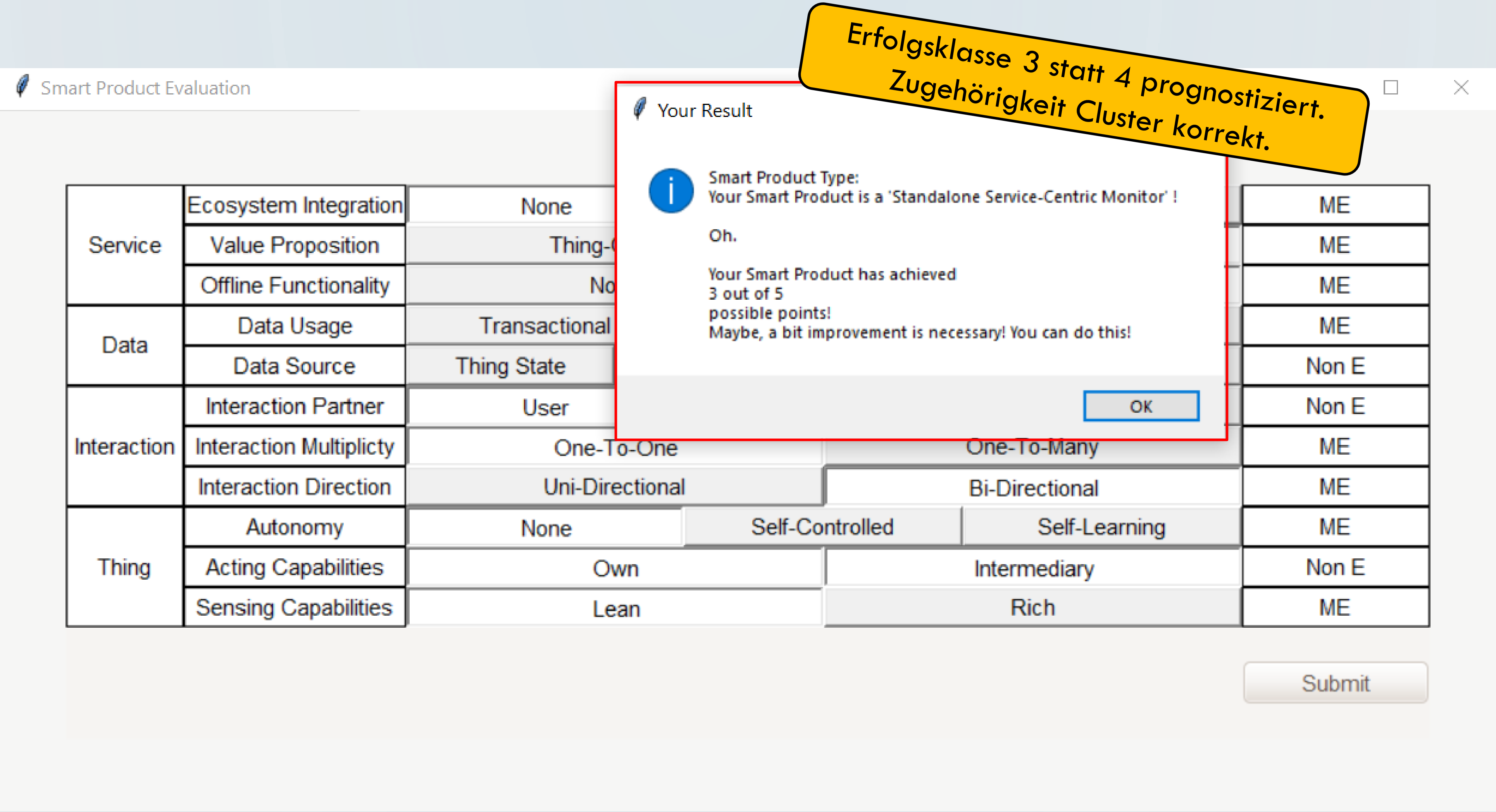
Thing	Autonomy	None	Self-Controlled	Self-Learning	
	Acting Capabilities	Own	Intermediary		
	Sensing Capabilities	Lean	Rich		

Erfolg: Klassen 1 bis 5. Geräte **in Klasse 5 am erfolgreichsten**.
Fitbit in **Klasse 4**, war **nicht Bestandteil** des **Trainingsdatensatzes**.

UMSETZUNG: FRONTEND USER INTERFACE



FAZIT

Learnings

- **Verbesserung Gütemaße** für den Erfolg von Smart Things **notwendig**
- **Mögliche Gründe** für unzureichende Ergebnisse:
    - **Zu viele Features** (d.h. Charakteristika)
    - **Erweiterung des Datensatzes** um weitere Smart Things, um repräsentative Stichprobe zu erreichen
    - **Geräte mit ähnlichen Eigenschaften sind unterschiedlich erfolgreich**

- **Gütemaße für** die **Cluster-Zuordnung** erzielen **gute Ergebnisse.** Somit ist eine Zuordnung aufgrund von Nutzereingaben möglich

- Evaluierung im **Vergleich mit anderen Verfahren** (z.B. Neuronale Netze)

ÜBERSICHT DATEIEN DIE IM PROJEKT ENTSTANDEN SIND

- Backend_Database_Create_New.py
- Backend_Database_Load.py
- Backend_Database_Read.py
- Backend_Feature_Reduction.py
- Backend_Support_Vector_Machine_Administration.py
- Backend_Support_Vector_Machine_Evaluation_User_Input.py
- Backend_User_Interface.py
- Frontend_Database_Create_New.py
- Frontend_Database_Write.py
- Frontend_Smart_Product_Class.py
- Frontend_User_Interface.py
- Principal_Component_Analysis_Results.csv
- smart_product.db
- Smart_Product_Data_float.csv
- Smart_Product_Data_float_ex_fitbit.csv