Research on Universe & Matter & Digital Transformation

ErUM = Erforschung von Universum und Materie

DIG-UM

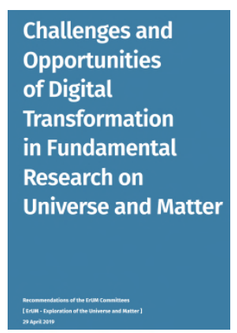
Prof. Dr. Martin Erdmann, RWTH Aachen University,
6-Feb-25

Research Mission






- We discover new particles yielding deep insights into the fundamental laws of physics
- Observe and explore distant galaxies, stars and new planets
- Investigate the structure and function of proteins drugs and viruses
- Discover new materials
- Observe chemical reactions in real-time



Objective: Accelerate Scientific Discoveries in Research on Universe & Matter





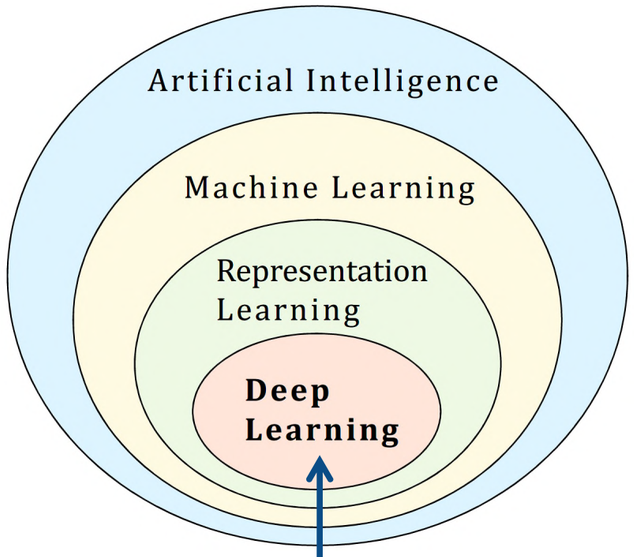

Forscherdrang:
New Results on Universe & Matter

Scientists with a PhD

Forschung mit Synchrotronstrahlung	KFS	2.300
Forschung mit Neutronen	KFN	1.600
Rat Deutscher Sternwarten	RDS	1.500
Hadronen- und Kernphysik	KHuK	1.500
Elementarteilchenphysik	KET	1.300
Astroteilchenphysik	KAT	500
Beschleunigerphysik	KfB	200
Forschung mit nuklearen Sonden und Ionenstrahlen	KFSI	100

20.000 = PhD scientists plus Students

Common understanding of terminology (?)



Artificial intelligence: overarching field of research that includes machine learning (also deep learning)

Machine learning: mathematical model with parameters optimized (trained) on data

Deep learning: machine learning with deep neural networks

Large language models: deep neural networks trained to search for the next most likely word (transformer-type networks such as ChatGPT)

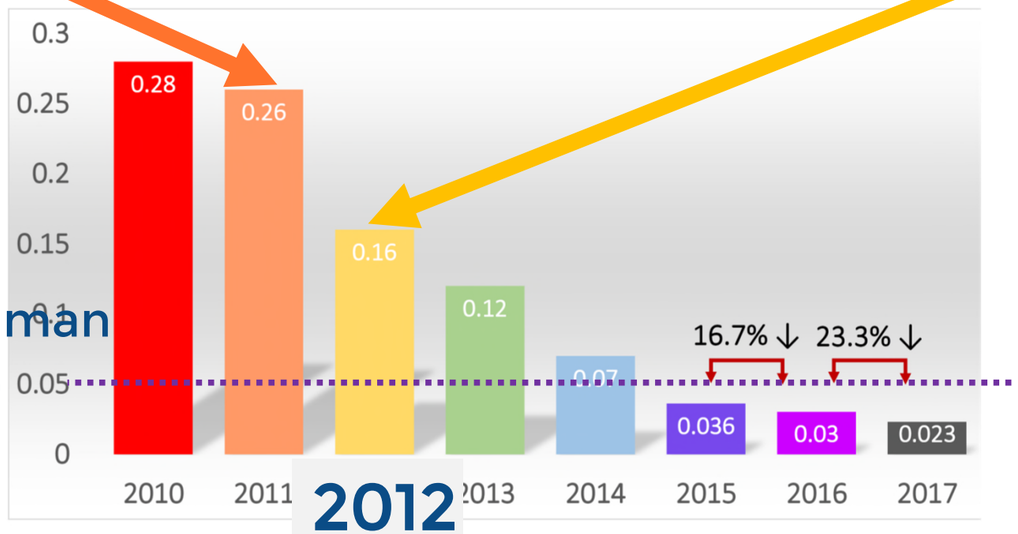
DIG-UM

Competition of Algorithms

Rule-based Systems if… then…

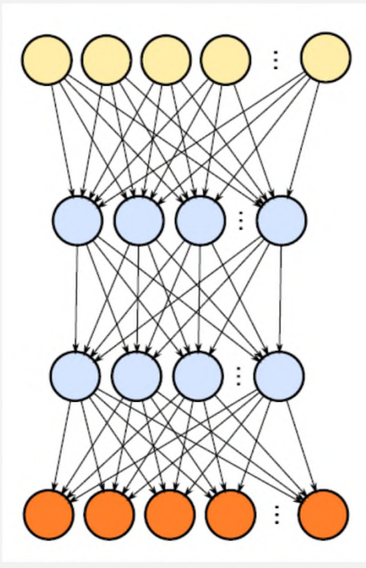
Classification error rate

1.2 million natural images with numerous aspects as criteria



Human 5%

Connectivity methods



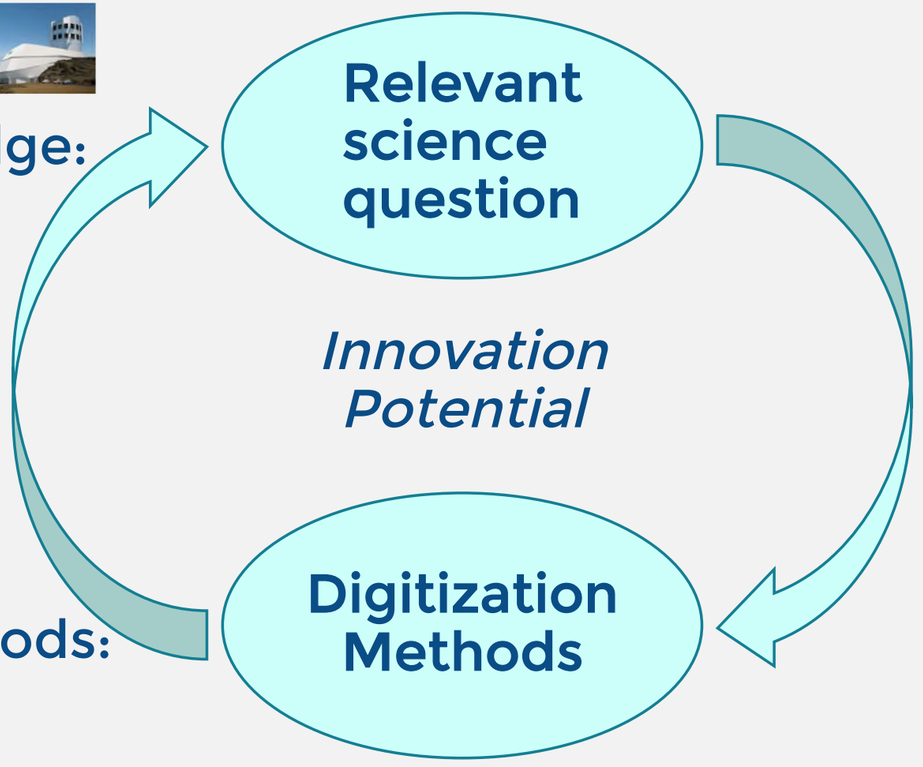
"Intelligence" by structure, not through content

O. Russakovsky et al, arXiv:1409.0575; K. He, X. Zhang, S. Ren, J. Sunar, arXiv:1512.03385
WMW Jie Hu, Li Shen (Oxford), Gang Sun, 2017 R. Kurzweil, Die nächste Stufe der Evolution, 2024

DIG-UM

Innovation: Domain Knowledge *and* AI

Science domain knowledge:



Know-how modern methods:

Adapt Computer Science Methoden, e.g. Deep Learning

- Fully connected
- Convolutional
- Graph
- Recurrent
- Autoencoder
- Generative Adversarial
- Normalizing Flows
- Diffusion
- Reinforcement
- Transformer
- Kolmogorov-Arnold
- Lorentz Boost

DIG-UM

Structure for Digital Transformation

Community Self-Organization

Komitee	
KAT	Astroteilchenphysik
KET	Elementarteilchenphysik
KfB	Beschleunigerphysik
KFN	Forschung mit Neutronen
KFS	Forschung mit Synchrotronstrahlung
KFSI	Forschung nuklearen Sonden & Ionenstrahlen
KHuK	Hadronen- und Kernphysik
RDS	Rat Deutscher Sternwarten

BMBF Funding

ErUM-Pro

Project funding for Experiments

ErUM-Data

120 M€ / 10 years

Digital Transformation

DIG-UM

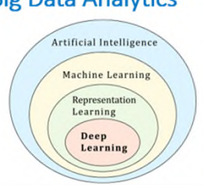
Overview Board (OB) 8 ErUM Committee Chairs, 1 Resource Provider Board Chair, 1 Spokesperson, 1 BMBF Representative, 1 PT-DESY Representative

Coordination

Spokesperson / 5 Co-spokespersons	Digitization Board (DB)	Resource Provider Board (RB)
	1 Spokesperson, 5 Co-spokespersons, 8 Experts from ErUM committees, 1 Resource Provider Representative	10 Resource Provider Representatives

Annual Conference of the ErUM-Data Working Groups

Topic Groups

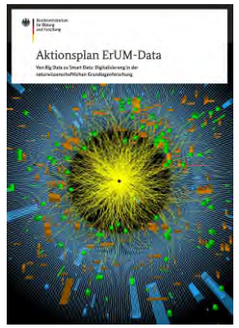
Federated Infrastructures	Big Data Analytics	Research Data	User Interface	Knowledge Distribution
				

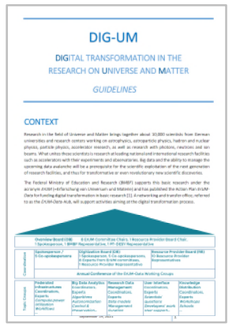
DIG-UM

Time Line Digital Transformation

2018 → 2019 → 2020 → 2021 → 2022 → 2023 → 2024 → **2025** → 2026 → …

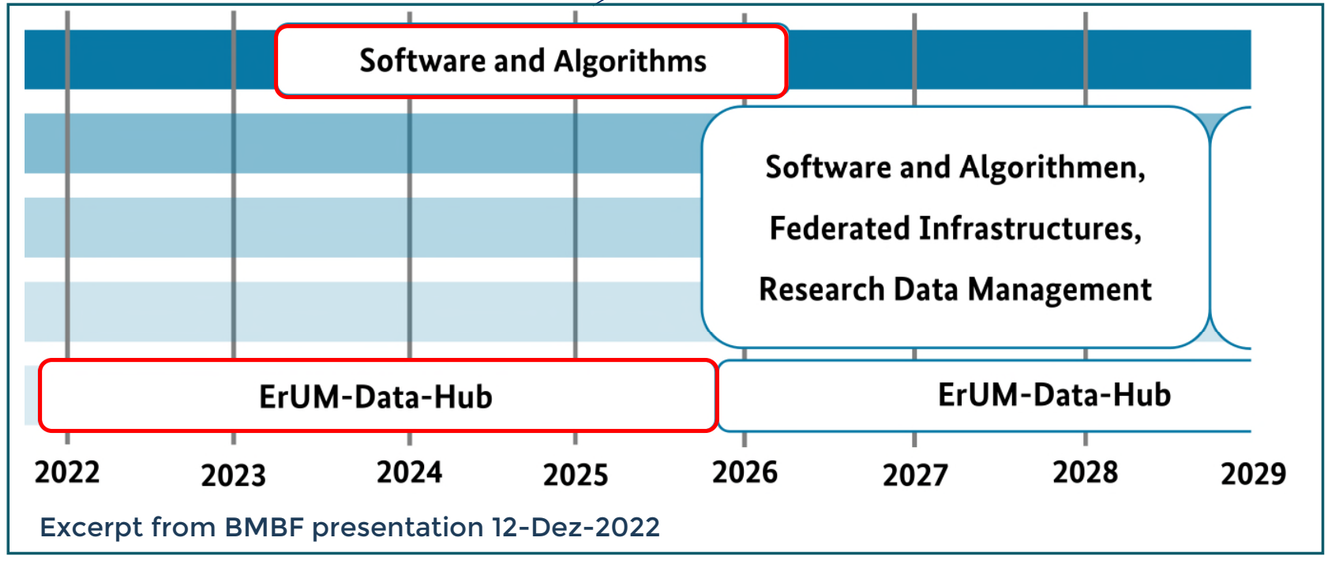
BMBF Workshop in Bonn





ErUM-Data: BMBF Funded Projects

ErUM-Data
120 M€
for 10 years



Excerpt from BMBF presentation 12-Dez-2022

DIG-UM

ErUM-Data Software & Algorithms

Hamburg/DESY Workshop 23.–24. Feb. 2023

	No. joint projects (Verbünde)	No. of projects (Vorhaben)	(Requested) funding
Sketches (Skizzen)			74.5 Mio. €
Full proposals (Anträge)	33% of sketches		30.7 Mio. € 41% of sketches
funded **17.5 M€**	19% of sketches / 59% of full proposals	59% of full proposals	~17.5 Mio. € 23% of sketches 57% of full proposals

Introduction to ErUM-Data from the PT-DESY *Marvin Berlinghof*
SR4, DESY 14:10 - 14:30

Verbundvortrag - VIPR *Marina Ganeva*
SR4, DESY 14:30 - 14:45

Verbundvortrag - KISS *Gregor Kasieczka*
SR4, DESY 14:45 - 15:00

Verbundvortrag - KI4D4E *Sven Simon*
SR4, DESY 15:00 - 15:15

Verbundvortrag - AISafety *Matthias Schott*
SR4, DESY 15:15 - 15:30

Verbundvortrag - ErUM-IFT *Torsten Ensslin*
SR4, DESY 15:30 - 15:45

Verbundvortrag - OPAL-FEL *Henrik Tünnermann*
SR4, DESY 16:15 - 16:30

Verbundvortrag - EvalSpek-ML *Sebastian Busch*
SR4, DESY 16:30 - 16:45

Verbundvortrag - ErUM-WAVE *Prof. Conny Hammer*
SR4, DESY 16:45 - 17:00

Vorstellung Verbundantrag - aNNomalie *Soeren Lange*
SR4, DESY 17:00 - 17:15

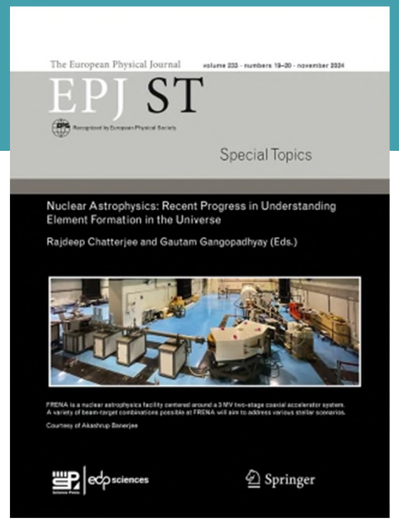
ErUM-Data-Hub
2,5M€ / 5 years

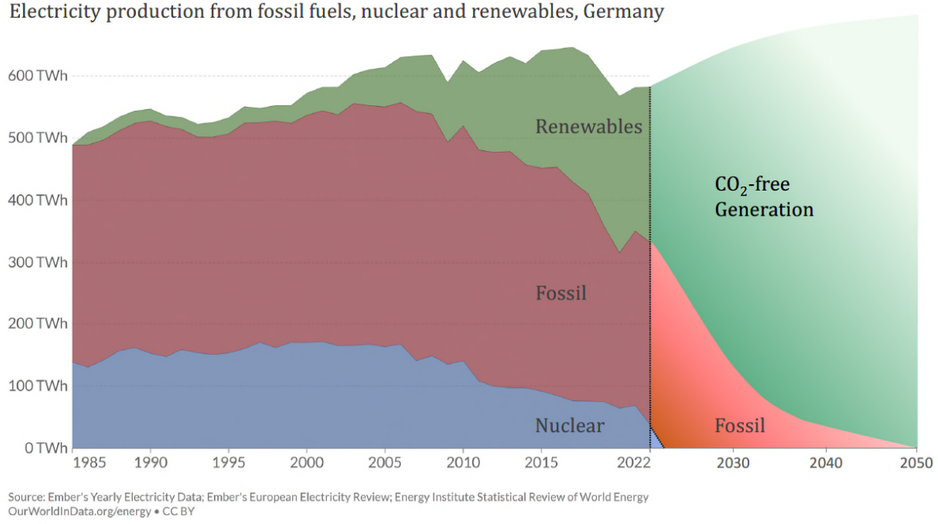
DIG-UM

Sustainability

4-day Workshop May 23

→ Awareness in daily research: balance ***knowledge gain*** with ***resource usage***





Portfolio of measures

Short term

Medium term

Longer term

Item	Call-to-action
	Immediately or on **short time scale** with little effort these measures that can be implemented:
S1	Raise awareness of the climate challenge at all levels.
S2	Disseminate knowledge of measures to address the challenge.
S3	Monitor and report energy consumption at job level.
S4	Consider carbon footprint for all investments and project plans.
	On a **medium time scale** of a few years the following measures can be realized:
M1	Make data FAIR to promote reuse.
M2	Reduce and compress data having the anticipated scientific value of the retained information and the resource requirements in mind.
M3	Optimize the choice of storing against re-calculating intermediate results.
M4	Use workflow management to make processing FAIR.
M5	Make software FAIR and reliable by following good software development practices and ensuring sustainable support.
M6	Design software for optimized energy consumption and provide tools to measure it.
M7	Continue research on potential of AI or other new technologies for efficient use of resources, but balance gain of research action against resource consumption of these developments.
M8	Monitor and report energy consumption at site and project level, provide information of the individual use per scientist/project/publication.
M9	Extend monitoring of resources beyond CO_2e (water, material etc.).
M10	Train scientists in good practices.
M11	Regularly review and update the CO_2e reduction plan.
M12	Strive to become a role model at all levels and help to establish sustainability in everyday life.
	A **longer term** coordinated planning is required for the following measures:
L1	Adjust computing in space and time to the availability of renewable energy, e.g. computing centers close to off-shore wind parks with a job scheduling using only or mainly the surplus available at a given time.
L2	Develop software and middleware that can respond dynamically to the availability of energy.
L3	Optimize power usage effectiveness.
L4	Re-use of produced heat.
L5	Adjust hardware lifetime considering emissions due to procurement and operation.
L6	Include the resources needed for continuous IT support into project planning.

https://doi.org/10.1140/epjs/s11734-024-01436-4

DIG-UM

Messages






- Research on Universe & Matter → Digital Transformation
- Innovation: Combine science domain knowledge with AI
- Structured approach: Community strategies and BMBF funding
- TRANSFER ?!

DIG-UM