Discussions on SFIs, Machine Learning and Artificial Intelligence, Quantum Technologies and more

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Background

The Research Council of Norway released on February 8, 2024, a notice about new centers for innovation. In the original timeline, a tentative deadline for calls was end of February 2024.

Summary from press release Feb 8 (in Norwegian)

1. AI-milliarden skal i hovedsak innrettes som utfordringsrettede sentra for kunstig intelligens.
2. Det skal utlyses 4-6 femårige, tverrfaglige og tverrsektorielle KI-sentre innenfor en ramme på 850 MNOK. Sentra kan ha ulik størrelse.
3. Disponering av resterende midler kan for eksempel omfatte forskerskoler, internasjonalt samarbeid og koordinering.

Styret ber administrasjonen og porteføljestyret identifisere muligheter for supplerende finansiering av sentrene og av satsingen. Styret ber administrasjonen foreslå mekanismer for koordinering, dialog, nasjonal og internasjonal synlighet av norsk KI-forskning og KI-innovasjon, og legge dette frem for Styret medio 2024.

Three main paths

1. Research into the consequences of artificial intelligence and other digital technologies for society. Central themes will be democracy, trust, ethics, economy, legal certainty, legal regulations, privacy, **teaching and learning**, arts and culture.
2. Digital technologies as a research area in itself, i.e. **research into artificial intelligence**, **digital security**, **next generation information technologies**, **new sensors and quantum technologies**.
3. Research on how digital technologies can be used for **innovation** in business and the public sector and how **artificial intelligence can be used in research in different disciplines**

Educational initiatives and international cooperation

In addition to the AI centers, 150 MNOK will go to other things. This can for example include research schools, international cooperations and coordinations.

What can it be?

Center for Artificial Intelligence and Quantum Technology (CAIQT)

Artificial intelligence and quantum technology are revolutionizing our life and work. They offer enormous advantages for science, economy, politics and civil society. The challenges and opportunities in the field of artificial intelligence and quantum technology call for new kinds of cooperation and new research directions.

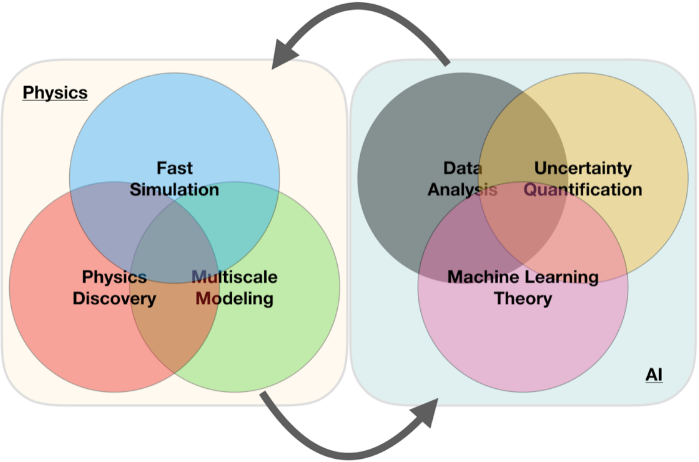
Our strengths

Several research activities on AI/ML for the physical sciences

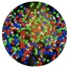
1. Research, applications and development of new methods in AI/ML
2. Research and development of quantum information science/technologies
3. Strong educational and training activities across disciplines
4. Many national and international collaborations across disciplines

- Partners at UiO: Math, Informatics, Chemistry, Bioscience, Geoscience, ITA, DScience and more
- Partners and collaborators outside UiO: CERN, SINTEF, OsloMet, SIMULA, Bank of Norway, DNB, Norwegian Meteorological Institute and more

AI/Machine learning. A simple perspective on the interface between ML and Physics

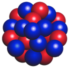


AI/ML in Nuclear Physics (or any field in physics)

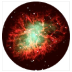


Hot and Dense Nuclear Matter

Hadrons

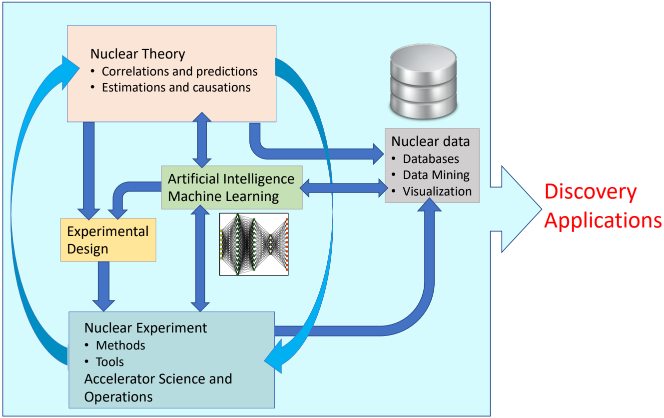


Atomic Nucleus



Nuclei in the Cosmos

Fundamental interactions



AI/ML for the Physical Sciences

1. Analyzing data from experiments, see for example from subatomic physics at https://www.sciencedirect.com/science/article/abs/pii/S0168900221004460?via%3Dihub
2. Research on quantification of uncertainties
3. Materials Science. See for example Predicting solid state material platforms for quantum technologies, Nature Computational Materials https://www.nature.com/articles/s41524-022-00888-3
4. Solving complicated quantum mechanical many-body systems with deep learning
5. Developing new ML algorithms with applications to quantum computing
6. Research on discriminative and generative AI/ML
7. Computational Neuroscience and more

Scientific Machine Learning

An important and emerging field is what has been dubbed as scientific ML, see the article by Deiana et al Applications and Techniques for Fast Machine Learning in Science, Big Data **5**, 787421 (2022)

The authors discuss applications and techniques for fast machine learning (ML) in science – the concept of integrating power ML methods into the real-time experimental data processing loop to accelerate scientific discovery. The report covers three main areas

1. applications for fast ML across a number of scientific domains;
2. techniques for training and implementing performant and resource-efficient ML algorithms;
3. and computing architectures, platforms, and technologies for deploying these algorithms.

ML for detectors

ELSEVIER

Engineering

Volume 6, Issue 3, March 2020, Pages 264-274

Research Artificial Intelligence—Review

A Survey of Accelerator Architectures for Deep Neural Networks

Yiran Chen [a], Yuan Xie [b], Linghao Song [a], Fan Chen [a], Tianqi Tang [b]

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https://doi.org/10.1016/j.eng.2020.01.007

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Abstract

Physics informed Machine Learning

Another hot topic is what has loosely been dubbed
Physics-informed deep learning.
It bridges the gap between first-principles based approaches and data-driven approaches. By incorporating physics information, machine learning models are encouraged towards solutions that are also physically meaningful and robust to uncertainties in the data. See the recent work on Physics-informed Machine Learning.

Collaborations

1. SINTEF
2. Norwegian Meteorological Institute
3. Simula

And more

- An important application of AI/ML methods is to improve the estimation of bias or uncertainty due to the introduction of or lack of physical constraints in various theoretical models.
- In theory, we expect to use AI/ML algorithms and methods to improve our knowledge about correlations of physical model parameters in data for quantum many-body systems. Deep learning methods show great promise in circumventing the exploding dimensionalities encountered in for example quantum mechanical many-body studies.
- Merging a frequentist approach (the standard path in ML theory) with a Bayesian approach, has the potential to infer better probabilitity distributions and error estimates.
- Machine Learning and Quantum Computing is a very interesting avenue to explore. See for example a recent talk by Sofia Vallecorsa.

Quantum technologies: what do we have?

1. We have at UiO extensive experimental, computational and theoretical activities in quantum science and technology
2. MiNaLab at UiO is one of the few experimental environments in Norway where we have a strong research activity on semiconductor based quantum technologies
3. Quantum sensing is a very active research direction at UiO, with great potential for discoveries

Five areas of quantum science and technology research in Norway

1. Basic quantum science
2. Quantum materials
3. Quantum sensing
4. Quantum communication and cryptography
5. Quantum computing

Main academic institutions and centers for basic quantum science

UiO

1. Physics and CCSE
2. Chemistry and Hylleraas center

NTNU

1. Physics and QSpin center

UiB? USN? UiS? UiT? UiA?....

Quantum materials

Universities

1. UiO: LENS, NAFUMA and structure physics, all at SMN
2. NTNU: Physics and QSpin, Department of Electronic Systems

Research institutes and companies (public and private)

1. SINTEF
2. Norwegian Metrology Service
3. Norwegian Defense Research Establishment and more

Quantum sensing

Universities

1. UiO: LENS at SMN
2. USN: Quantum technology group

Research institutes and companies (public and private)

1. SINTEF
2. Kongsberg group
3. Norwegian Metrology Service
4. Norwegian Defense Research Establishment
5. Equinor, Tomra, Jotne, Sony and more

Quantum communication and cryptography

Universities

1. UiO: Math, Physics and LENS at SMN
2. NTNU: Department of Electronic Systems

Research institutes and companies (public and private)

1. SINTEF
2. Simula
3. Norwegian Metrology Service
4. Norwegian Defense Research Establishment
5. IBM, Microsoft and other
6. Bank of Norway, DNB, insurance companies and more

Quantum computing

Universities

1. UiO: Math, Physics and CCSE, Chemistry and Hylleraas
2. NTNU: Qspin
3. OsloMet

Research institutes and companies (public and private)

1. SINTEF
2. Simula
3. Norwegian Metrology Service
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5. IBM, Microsoft and other
6. Bank of Norway, DNB, insurance companies and more

Education, what do we have?

1. **New study direction on Quantum technology** in Bachelor program Physis and Astronomy, starts Fall 2024. Three new courses:
   - FYS1400 Introduction to Quantum Technologies
   - FYS3405/4405 Quantum Materials
   - FYS3415/4415 Quantum Computing
2. **Developed Master of Science program on Computational Science**, started fall 2018 and many students here work on quantum computing and machine learning
3. New study direction in Physics Master on Quantum Science and technologies
4. New study direction in Computational Science program on AI and QT
5. Developed courses on machine learning, from basic to advanced ones, FYS-STK3155/4155 and FYS5429/9429
6. Developed advanced course on quantum computing and quantum machine learning, FYS5419/9419
7. Since 2018 organized and taught many international schools and intensive courses on quantum computing and machine

Important issues to think of

1. Lots of conceptual learning: superposition, entanglement, quantum applications, etc. Opens for Physics Education research studies
2. Coding is indispensable.
3. Teamwork, project management, and communication are important and highly valued
4. Engagement with industry: guest lectures, virtual tours, co-ops, and/or internships.

QT observations

1. Students do not really know what QT is.
2. ML/AI seen as black boxes/magic!
3. Students perceive that a graduate degree is necessary to work in QT. A BSc will help.

Future needs a center or EDU program could address

1. There are already great needs for specialized people (PhDs, postdocs), but also needs of people with a broad overview of what is possible in ML/AI and/or QT.
2. There are not enough potential employees in AI/ML and QT . It is a supply gap, not a skills gap.
3. A BSc with specialization is a good place to start
4. It is tremendously important to get everyone speaking the same language. Familiarity with the vernacular of quantum mechanics is a big plus.
5. There is a huge list of areas where technical expertise may be important. But employers are often more concerned with attributes like project management, working well in a team, interest in the field, and adaptability than in specific technical skills.
6. Collaborations with companies like IBM and other universities, see for example IBM's partnership with universities.

Possible questions for discussion

1. Should we focus only on QT or try to be broader (that is AI+QT)?
2. Can we develop educational modules (courses, certificates, degrees and more) in AI and/or QT for people outside universities?
3. Should we establish a working group which prepares the ground for an eventual call?