VISUAL INTELLIGENCE

Annual Report **2021**

Centre for Research-based Innovation

Contents

Cover illustration: Torger Grytå – Editorial team: Robert Jenssen, Inger Solheim, Line Eikvil and Anne S. Solberg. Design and layout by Torger Grytå and Siri Jachlin, Graphics Department, UiT The Arctic University of Norway.

Anita Schumacher, CEO University Hospital of North Norway. Photo: Jonathan Ottesen, UiT.

Words from chair of board

It is a true privilege to be chair of the board of Visual Intelligence. Technology based on deep learning for image analysis and AI for data analysis in general are becoming crucial components for data-intensive institutions, including my own institution, the University Hospital of North Norway (UNN). We need to be at the forefront of research in AI in order to gain value from data. Visual Intelligence is an important contributor in this development towards future innovations. Visual Intelligence is an exciting consortium spanning several important application domains in Norwegian society covering health, the marine sciences, energy and earth observation. Coming from the health sector, it is intriging to see that the deep learning and AI research challenges that companies such as Equinor, Kongsberg Satellite Services, Terratec, or GE Vingmed Ultrasound are facing in order to innovate their use of image data are so similar to those that the public sector institutions such as the Cancer Registry, the Institute of Marine Research, or UNN and Helse Nord IKT are facing. A range of Visual Intelligence workshops in 2021 have shown that we have much to learn from each other in such a truly interdisciplinary collaboration, creating opportunities and great potential for synergies. I am already seeing the contours of promising results coming out of these collaborations. As a research centre, we are training the next generation young researchers within the field, and we have set up strong international collaborations. As the chair of the board for Visual Intelligence, I look very much forward to the continuation of this exciting journey for our consortium and for Norway as a whole!

Line Eikvil and Anne S. Solberg (CO-Directors). Photo: Norwegian Computing Center.

Inger Solheim (Administrative coordinator) and Robert Jenssen (Center Director). Photo: Knut Jenssen.

First year of Visual Intelligence

It has been an exciting first year for SFI Visual Intelligence as a research centre! Together, we are taking important steps on our deep learning journey towards innovations in image analysis for our industry and public sector partners and beyond.

Naturally, much efforts have been invested into building the long-term foundation for our interdisciplinary consortium, to recruit, and to set up joint research activities. We have employed several new PhD students and researchers for working on Visual Intelligence projects. The first PhD students started already in January 2021, and we are truly happy to have been able to attract very good candidates with diverse backgrounds. To strengthen Visual Intelligence we have also recruited both new research scientists and new faculty members, several coming from very strong institutions in Europe and the US.

At UiT, Visual Intelligence is now a major component in a new interdepartmental study program in AI. The first batch of students were enrolled fall 2021. At UiO, Visual intelligence is a natural part of a new section for machine learning at department of informatics and a new center for data science and computational sciences established in 2021.We are very pleased to contribute to increased access to highly educated, qualified personnel in Norway in AI in these ways.

Already in the first year of operation, we have managed to obtain concrete results in close collaboration between the research partners and the user partners. Some of these results are in the form of publications, partially building on already ongoing collaboration and in synergy with associated projects, others are in the form of pilots and new methods to extract information from user partner data to lay foundation for innovations. In this way, we shape the future and create innovations that will have impact on lives and society!

We have set up a bi-weekly Visual Intelligence online seminar series and organized a range of specialized scientific workshops and innovation workshops, forging together our respective research institutions as well as the industry and public sector partners. Of course, corona put some limitations, but Visual Intelligence is in any case a modern type of research centre composed of strong research hubs working under a unified leadership, and we rely therefore to a large degree on digital aids in any case.

Visual Intelligence spans many actors across Norway and by being forged together we create the critical mass which is needed to take a leading role internationally. Our Northern Lights Deep Learning (NLDL) conference, organized in Tromso in January 2021, was a huge success, exposing the international community in deep learning to Visual Intelligence, and bringing the best of international deep learning research to be presented in Norway. As the only research centre in Norway, we signed in 2021 a Memorandum of Agreement with The Alan Turing Institute. This will bring unprecedented opportunities. We are proud to interact with such a renown institute.

We are also immensely proud of our early career researchers associated with the Visual Intelligence scientific program and the establishment of the Visual Intelligence Graduate School (VIGS). The VIGS brings together researchers at an early stage in their career and helps develop transferable skills, helps to promote diversity and gender balance, and helps to integrate the principles of ethics, open science and sustainability into all aspects of Visual Intelligence. With such talented researchers coupled with our strong team of industry and public sector partners, we look very much forward to the years to come!

Robert Jenssen
Centre Director

Anne Solberg
Co-Director

Line Eikvil
Co-Director

Inger Solheim
Administrative Coordinator

Vision

Visual Intelligence shall be an international leader within deep learning research for providing complex image analysis innovations.

The consortium partners come from different business areas in industry and in the public sector and they all rely on complex image data for sustainable value creation. This poses shared research challenges within deep learning and AI. Visual Intelligence exploits this crucial cross-fertilization in the research and innovation.

Objectives

Our main objective is to unlock the potential of visual intelligence across the main innovation areas medicine and health, marine science, the energy sector, and earth observation by enabling the next generation deep learning methodology for extracting knowledge from complex image data.

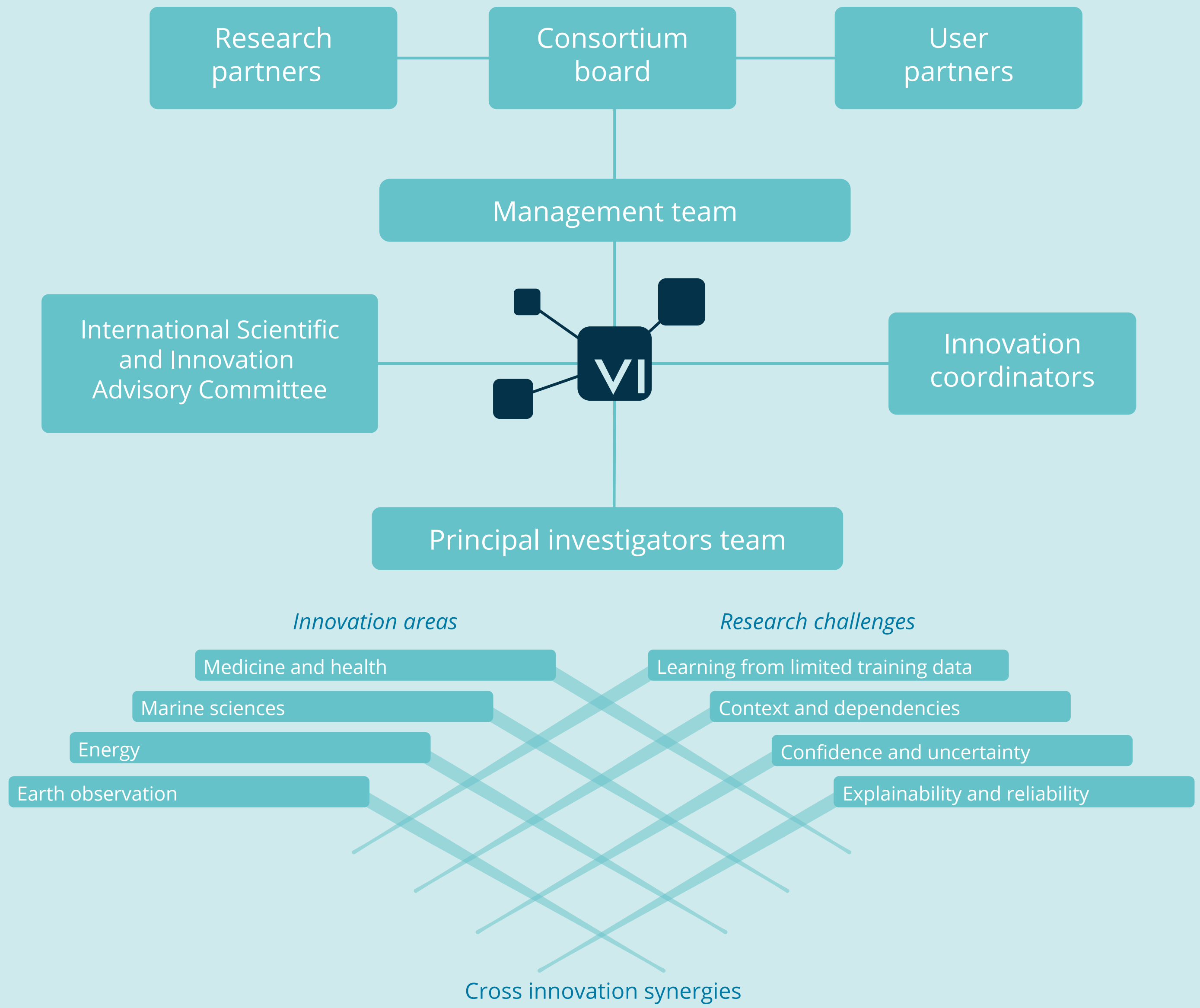
This will be accomplished through analysis of complex imagery for real-life applications by solving our secondary objectives, permeating all innovation areas. They are:

To develop deep learning solutions

- For learning from limited data
- For exploitation of context, dependencies, and prior knowledge
- For estimation of confidence and quantification of uncertainties
- For explainable and reliable predictions

The innovations result in new and improved products and services for value creation for the consortium partners.

Organisation



The management team

Robert Jenssen
Director
UiT The Arctic University of Norway

Anne Solberg
Co-Director
University of Oslo

Line Eikvil
Co-Director
Norwegian Computing Center

Inger Solheim
Administrative Coordinator
UiT The Arctic University of Norway

The board

Anita Schumacher – *Chair*
The University Hospital of North Norway

André Teigland
Norwegian Computing Center

Erik Steen
GE Vingmed Ultrasound

Jens Grimsgaard
Equinor

Leif Erik Blankenberg
Terratec

Giske Ursin
The Cancer Registry

Tom Robert Elvebu
Helse Nord IKT

Gudmundur Jøkulsson
Kongsberg Satellite Services

Solveig Kristensen
University of Oslo

Arne Smalås
UiT The Arctic University of Norway

Frode B. Vikebø
The Institute of Marine Research

Visual Intelligence graduate school committee

Alba Ordoñez
Principal investigator
Norwegian Computing Center

Sarina Thomas
Postdoctoral researcher
University of Oslo

Kristoffer Wickstrøm
Doctoral Research Fellow, UiT
UiT The Arctic University of Norway

International scientific and innovation advisory committee

Guoying Zhao
University of Oulu

Julia Schnabel
Technical University of Munich & King's College London

Zheng-Hua Tan
University of Aalborg

Innovation coordinators

Lars Ailo Bongo
Professor
UiT The Arctic University of Norway

André Teigland
Norwegian Computing Center

Line Eikvil
Co-Director
Norwegian Computing Center

Meet consortium partners

We asked three of our consortium partners to tell us:

1. What are your thoughts on Visual Intelligene from your perspective?

2. What gains do you envision from participating in Visual Intelligence?

Erik Steen

Chief Engineer, GE Vingmed Ultrasound

1. I think Visual Intelligence is off to a good start with lots of projects going on, regular seminars and very nice web pages. In general I feel it is very professionally lead. Envision that Visual Intelligence will help us secure that the expanding set of AI features in our products are based on the best possible AI technology. It is very important that automated measurements, analysis of ultrasound data and diagnostic support applications gives reproducible and accurate results on a wide range of patients. I also envision that we will learn from research in other application areas than our own and that we can capitalize on these results in our own research and development.

2. Our initial participation will be a bit limited due to resource constraints so in the two first years we mainly focus on methods for improving our automated distance measurements so that they work well on a wider range of patients than existing methods. I expect the results to be directly applicable to future product offerings. Later in the project we plan to expand our participation and work more broadly on new challenges mainly related to diagnostic support and advanced analysis of ultrasound data and potentially also making our imaging methods more robust.

Erik N Steen is currently working as Chief Engineer in the GE Healthcare Cardiovascular ultrasound business where he is responsible for technology roadmaps, innovation and research. He has a PhD in Image processing and Visualization from NTNU and is currently engaged in several research programs.

Guðmundur Jökulsson

Chief Architect of Processing and Analysis, Kongsberg Satellite Services (KSAT)

1. In 2018, KSAT started to establish an internal development team, working on Machine Learning, aiming to automate our vessel detection and oil-spill analysis from EO sensor data. We executed an initial experimental R&D project to test the feasibility of applying ML for detection and characterization of oil on water in radar images from the Sentinel-1 SAR (radar) sensor. The project gave positive indications but left many questions unanswered, regarding the chosen model/methodology, the quality of our training datasets when combining data from multiple SAR instruments, as well as quantification of the reliability, confidence, and quality of the results in general.

   When we were invited to join Visual Intelligence, we saw a perfect opportunity to join with credible state of the art expertise and research capacity, to continue our development in the AI area. KSAT has detailed expertise on the capabilities and characteristic of the specific EO sensors we use, but no real capacity to perform research on the more generic aspects of ML/DL methodologies best applicable to create good training data, to validate and quantify correctness, and to provide required traceability of the results.

   Together, the research institutions in VI represent broad experience in working with analysis of EO data, as well as being at the research front in application of deep learning. Further, the other innovation partners in VI are working on data from relatable type of image-generating sensors, and similar challenges regarding training data - which hopefully will make advances in the key research topics applicable across the specific sensors and application areas.

2. The marked value of Earth Observation applications, and in particular Maritime Surveillance services, is inherently dependent on the near-real time aspect to provide "actionable" information to the user. As the satellite industry is rapidly developing to launch constellations of relatively inexpensive EO satellites, the feasible temporal coverage of a given area increases substantially, and the available amount of sensor data is growing fast. In the coming years it is not sustainable to handle such volumes of sensor data by traditional time-consuming signal analysis processing and manual quality control.

   For KSAT, to stay competitive in the Maritime Surveillance Service market, it is essential to develop fully automated near-real time analysis of the sensor data we use in our services, without compromising the quality or confidence in the information results. Through our participation in Visual Intelligence, KSAT aims to develop fully automated surveillance services, with well documented quality, traceability, and confidence in the results.

   As we build our internal development teams to this capacity, we hope that our participation in VI will provide us both guidance in our development work and directly applicable results for us to implement operationally in our service production. We also expect to educate PhD. candidates in the specific challenges regarding EO/SAR data and AI, and thereby evolve a basis for recruitment to our development teams. Finally, the VI program participation is a valuable platform and a forum for our staff to form relations with highly qualified persons in the field of AI, to discuss with – to test ideas and exchange experiences in the progress of our work.

Guðmundur Jökulsson is currently working as the Chief Architect of Processing and Analysis at KSAT. He has previously been Director, Systems Development, at KSAT, leading the development on internal EO systems and customer services. Jökulsson worked several years as a researcher and research manager at Norut (now NORCE) prior to joining KSAT.

Nils Olav Handegard

Principal Scientist, Institute of Marine Research

1. Visual intelligence provides access to both technical machine learning expertise as well as meeting place for institutions and companies using these methods in their business. I find this combination particularly interesting since it both has a science component and provides context to the development of new methods. This puts more emphasis on domain knowledge than traditional theoretical developments, which I think is the key to make progress. I think this boundary between applied and theoretical science is very useful for the students involved in the centre. It provides a theoretical foundation that will be very important for them as well as it provides insight into how different companies and institutions are using these methods in practise.

2. I expect that visual intelligence will provide solutions for some of our data processing bottlenecks, but perhaps even more important, the centre provides a community where we can share challenges and solutions across the different domains represented in visual intelligence. I am also leading another SFI called CRIMAC, and we have been able to establish a good collaboration between the centres. I am motivated to further explore this collaboration, and I believe it will benefit both centres.

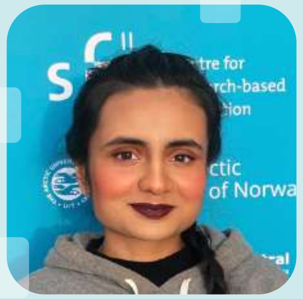
Nils Olav Handegard holds a PhD in applied mathematics and works within the field of fisheries acoustics at the Institute of Marine Research. He has been part of the science leadership group in the international council for exploration of the sea (ICES), and has extensive project management experience, leading several large interdisciplinary projects. He is the director of the CRIMAC SFI.
[https://www.hi.no/en/hi/about-us/employees nils-olav-handegard](https://www.hi.no/en/hi/about-us/employees/nils-olav-handegard)

Top: Nils Olav Handegard. Photo: Erlend Astad Lorentzen, Institute of Marine Research. Bottom: Erik Steen. Photo: Visual Intelligence.

Meet early career researchers

We asked three of our early career researchers to:

1. Tell us about your background
2. Why have you chosen to pursue a career in AI?
3. What attracted you to the Visual Intelligence program?



Suaiba Amina Salahuddin

UiT The Arctic University of Norway

1. My name is Suaiba Amina Salahuddin. I am Bangladeshi and have completed my BEng and MSc degrees at King´s College London. My research and educational background were focused on Biomedical Engineering and AI for Medical Imaging.

2. During my studies and research experiences I realised my passion for engineering effective healthcare technologies particularly those incorporating novel machine learning and AI-driven techniques for challenging pathologies.Therefore, I now wish to continue my academic career with a PhD focused on AI for medical imaging applications.

3. Having gathered experience within the field of Deep Learning I wanted to expand on my knowledge and work on a new challenge. With this motivation I decided to pursue a research opportunity within the SFI Visual Intelligence program, where I am currently working on Few Shot Segmentation, seeking to leverage only few labelled samples to train a Deep Neural Network that can segment previously unseen classes for medical images.

James Claxton

University of Oslo

I came to Norway in late 2019 to join a Physics master's programme at the University of Oslo. Under the supervision of professor Pavlo Mikheenko, I studied the magnetic properties of biologically produced palladium nanoparticles. This was fascinating research and at the same time I was developing my understanding in machine learning. My course projects gave me free rein to explore and be creative - to investigate AI methods of my choice.

My thesis work did not include a great deal of machine learning. But I did see opportunities for solving physics problems using AI. I was fascinated that complicated physics challenges were being tackled by researchers in computer vision. I believe that AI has high leverage and that we can use it to rapidly better the situation of people around the globe.

In early 2021 I came across the Visual Intelligence (VI) bi-weekly meetings. These meetings were interactive and attracted me. I felt that I was exposed to novel deep learning methods and had the opportunity to direct my questions to researchers in the field. I saw the open positions in the VI programme and knew that I had to apply. I felt that this would give me a strong background in deep learning and the opportunity to contribute significantly to evolving AI for the benefit of others.

Ingrid Utseth

Norwegian computing center

1. I have a bachelor's degree in Environmental Physics from the Norwegian University of Life Sciences and a master's degree in Computational Science, with a focus on computer vision, from the University of Oslo. After completing my master's degree in 2020 I have been working as a research scientist at the Norwegian Computing Center, with a focus on image analysis and AI.

2. AI is a relatively new research field, and it is growing very quickly. When I first started taking classes on AI, being a small part of this revolution in computer vision seemed very appealing to me. With a wide range of challenges waiting to be solved, and new solutions constantly being published, I figured a career within AI would give me the opportunity to continue learning and growing. AI methods can be applied to a wide range of problems across many fields, and I find it very exciting and rewarding to witness research being put into practise.

3. First and foremost, I have found that the Visual Intelligence program is a great way for me to get in touch with other researchers and exchange knowledge across research institutions and universities. Through the Visual Intelligence Graduate School, I have been able to meet and befriend early career researchers like myself (which is normally quite difficult once you are no longer a university student). Meetups and regular seminars have helped me keep up with new research and get inspiration for my own work. Since the opening of the Visual Intelligence program last year, the research I am doing through the program and its partners has been an interesting and import part of my workweek.

Visual Intelligence in brief
2021

January

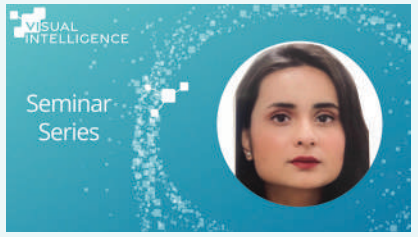
Visual Intelligence is officially opened by rector Anne Husebekk at UiT The Arctic University of Norway.

The Northern Lights Deep Learning Conference is Visual Intelligence's international flagship conference.

February

First PhD students recruited

March



Bi-weekly online Visual Intelligence Seminar series launched.

June

The Alan Turing Institute

Collaboration agreement with The Alan Turing Institute Signed.

July

Co-organized the Midnight Sun Conference on Clinical use of AI.

August

New 5-year master study program in AI established at UiT.

September

New faculty members employed in Visual Intelligence. Benjamin Ricaud, for instance, joins from EPFL.

SPKI

Visual Intelligence is instrumental to the establishment of the UNN-UiT "Senter for pasientnær kunstig intelligens"/SPKI.

Visual Intelligence Graduate School (VIGS).

October

The Visual Intelligence Days gathered the whole consortium for two days.

November

The Digital Technology Innovation Lab is established at UiT. The Lab enables student startups and fosters innovation culture.

Innovation highlights

New methodology for deep learning for localization and prediction of Tobis versus other fish/no fish based on acoustic image data together with partner The Institute of Marine Research (IMR).

A system for detection, location and classification of seal pups on sea ice has been developed using aerial photography in collaboration with partner IMR.

New methodology for measuring the dimensions of the left heart valve using newly developed methods for deep learning on ultrasound images of the heart in collaboration with partner GE Vingmed Ultrasound (GEVU).

Method for quantifying lymphocytes as prospective biomarkers for clinical pathology. The method works as an interactive tool for clinicians at the University Hospital in Northern Norway (UNN).

Method for simplifying tumor imaging with dynamic PET by evading blood sampling together with partner UNN.

A preliminary method for the detection of liver metastases based on CT scans of patients diagnosed with bowel cancer by partner UNN. Expanded via text from radiology reports.

Method for detecting changes in building mass based on aerial photos from partner Terratec in order to be able to partially automate updating of Terratec's map databases.

Methodology for learning motion and changing structures without manual annotation tested for seismic imagery together with Equinor.

Improved detection of cancer in mammography images by identifying important areas in the images, tested on Norwegian data from the Cancer Registry's mammography program.

First tests to compare a single-stage object detection model with Kongsberg Satellite Service's (KSAT's) existing multi-stage platform. Infrastructure for massive processing and deep learning set up at KSAT.

Reseachers Srishti Gautam, Suaiba A. Salahuddin, Stine Hansen, Michael Kampffmeyer, Eirik Østmo, Luigi Luppino and Samuel Kuttner visiting the Positron Emission Tomography (PET) Center at the University Hospital of North Norway. Photo: Knut Jenssen.

Deep learning derived input-function in dynamic positron emission tomography imaging

Researcher Samuel Kuttner (UNN & UiT) explains: “Positron Emission Tomography (PET) imaging plays a vital role in cancer diagnostics. Arterial blood sampling is required for performing state-of-the-art measurements from dynamic PET examinations. Arterial cannulation is however laborious and time-consuming. This innovation aims at overcoming the need for blood sampling required for dynamic PET. Based on a large database of dynamic PET images with arterial blood sampling, we are building deep learning-based models that predict the arterial blood curve directly from the PET images. This will significantly simplify tumor imaging with dynamic PET by evading of blood sampling. The invention is a result of a unique interdisciplinary collaboration between Visual Intelligence and the Norwegian Nuclear Medicine Consortium 180°N.”

The disclosure of invention (DOFI) was submitted Nov 25th, 2021. Inventors are: Samuel Kuttner, Luigi Luppino, Kristoffer Wickstrøm, Nils Midtbø, Michael Kampffmeyer, Robert Jenssen, Rune Sundset.

PhD student Changkyu Choi. Photo: Jonatan Ottesen.

Deep learning to detect fish species from acoustic imagery

In this research, we developed a novel semi-supervised deep learning method for multi-frequency echosounder data. Multi-frequency echosounder data, known as sonar data, is a vital source of visual information to understand the underwater environment on a large scale. Since data analysis is used to establish the annual catch limit of the fish harvest by estimating the abundance, accurate analysis methods can have significant implications for global fisheries and policy authorities. So far, heuristic analysis is a common approach, where the expert operators manually delineate the fish school region and annotate the species of the school using auxiliary information.
This manual process is costly in time and budget and vulnerable to human bias due to excessive reliance on the operators' tacit knowledge. Therefore, there is a need for an integrated and automated analysis method with reduced human intervention. Our proposed analysis method is based on deep learning. Deep learning is one of the representative AI frameworks, which autonomously learns the solution of the given task from the training data with minimized external intervention. Supervised deep learning is a standard learning scheme that leverages fully annotated training data. Despite the outperforming results against the traditional analysis methods, supervised deep learning has a fundamental research challenge: an excessive dependence on the annotated training data.
Our proposed method considerably reduces the dependency on the annotated training data while efficiently exploiting the available annotated data, referred to as semi-supervised deep learning. The key idea of our method is to make the deep learning model more intelligent by employing another unsupervised clustering algorithm in addition to the supervised analysis algorithm. Hence, two algorithms jointly learn in one deep learning model. Extensive experiments validated that our semi-supervised method achieves comparable analysis performance to the supervised deep learning method with fully annotated data while leveraging only 10 percent of the annotated training data in addition to unannotated training data.

Read more: C. Choi, M. Kampffmeyer, N. O. Handegard, A.-B. Salberg, O. Brautaset, L. Eikvil, R. Jenssen, "Semi-supervised target classification in multi-frequency echosounder data," ICES Journal of Marine Science, 2021.

News story in Fiskeribladet Tekfisk (Norwegian): [https://www.fiskeribladet.no/tekfisk/arbei-det-hans-sparer-forskerne-for-store-ressurser-og-apner-for-et-selvstyrt-fiskeri/2-1-1056409](https://www.fiskeribladet.no/tekfisk/arbeidet-hans-sparer-forskerne-for-store-ressurser-og-apner-for-et-selvstyrt-fiskeri/2-1-1056409)

Work in synergy with associated project Cogmar. More information at:
[https://www3.nr.no/nb/projects/cogmar-ubiq-uitous-cognitive-computer-vision-marine-ser-vices](https://www3.nr.no/nb/projects/cogmar-ubiquitous-cognitive-computer-vision-marine-services)

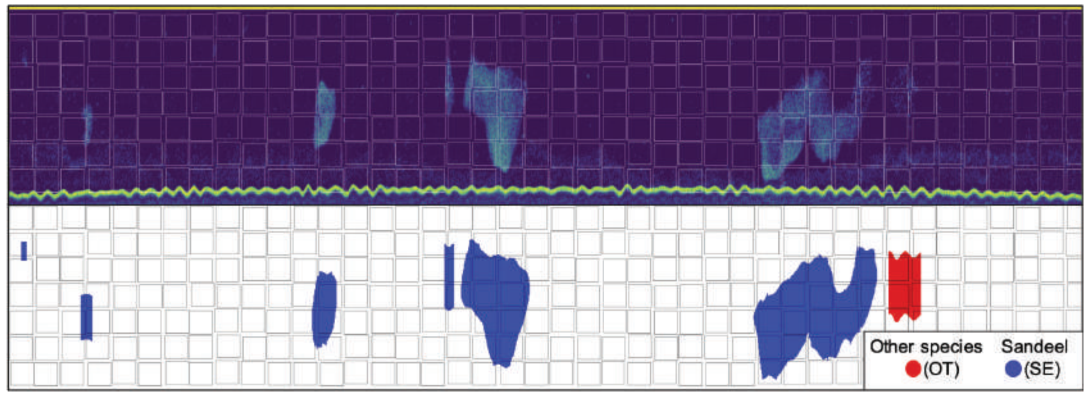


Figure: Echosounder imagery. Changkyu Choi, UiT.

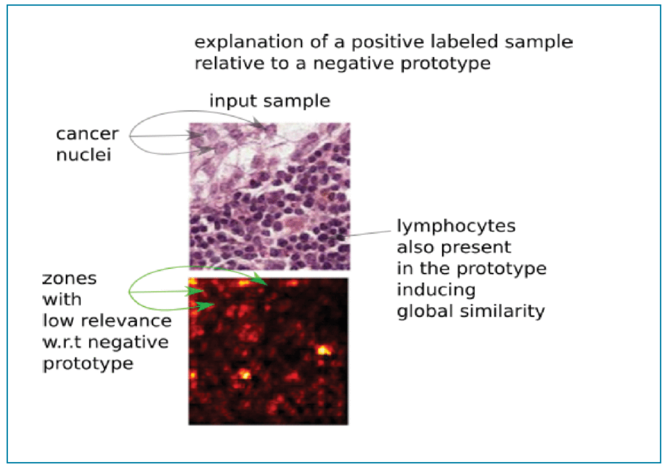


Figure: Explainable deep learning can aid computational pathology. Alexander Binder, UiO.

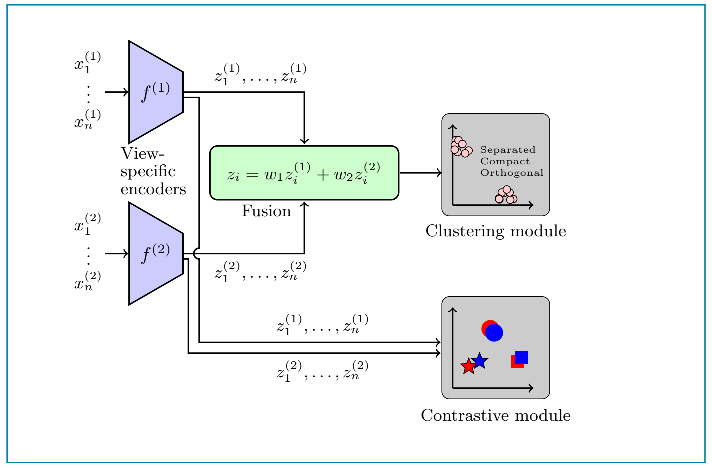


Figure: New deep learning methodology for multi-view clustering. Daniel Trosten, UiT

New method for interpretable deep learning and outlier detection

When neural networks are employed for decision-making, it is desirable that they provide explanations for their prediction in order for us to understand the features that have contributed to the decision.
At the same time, it is important to flag outliers for in-depth verification by domain experts. An outlier is a sample which is very different from what has been used at training time, for example when a system used to classify microscopies is presented with a landscape photo, or a too dark or damaged image. In this work we propose to unify two differing aspects of explainability with outlier detection as the third step.

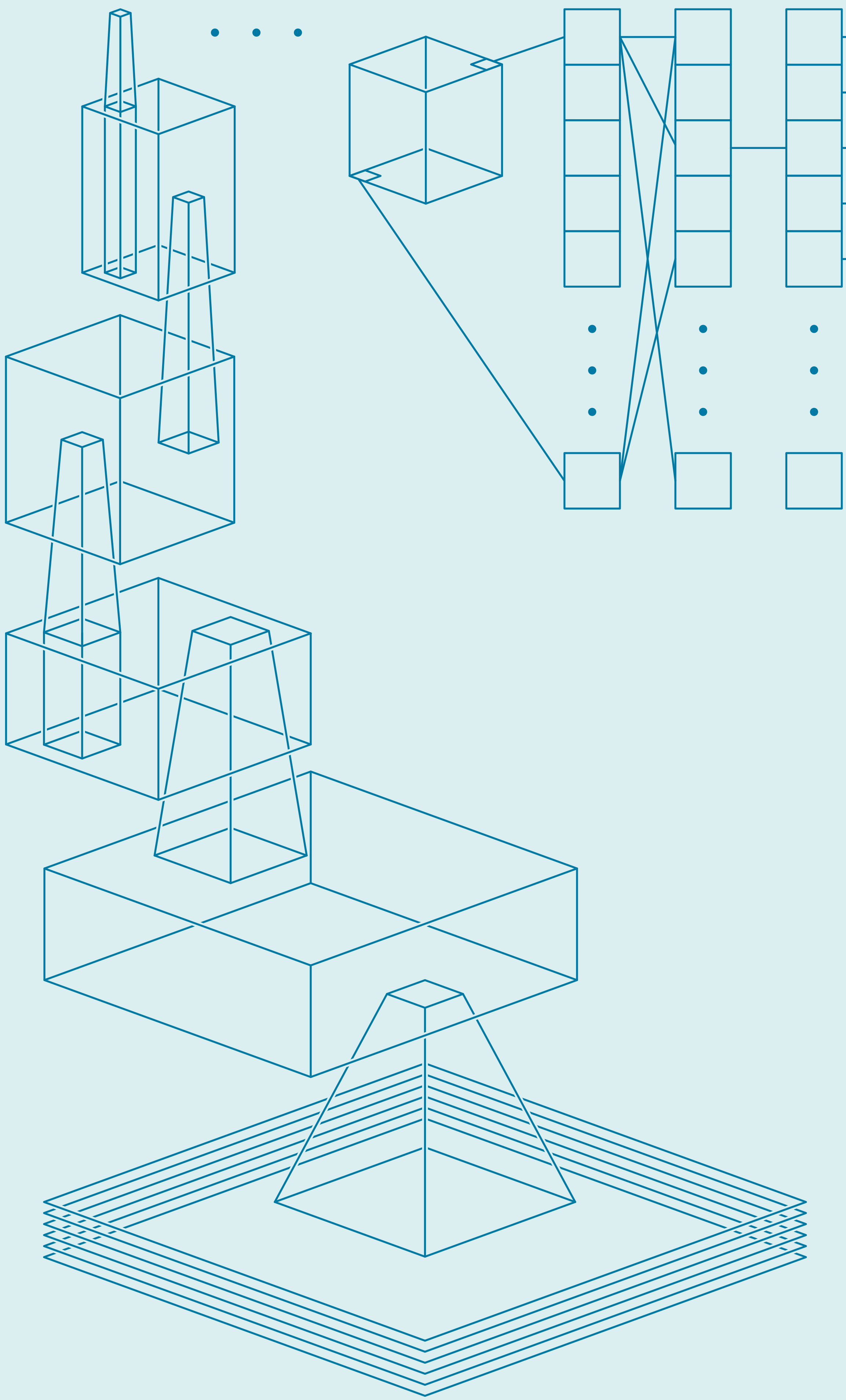
For the first aspect, we argue for a broader adoption of prototype-based student networks capable of providing an example-based explanation for their prediction. Unlike common neural networks, which learn synthetic patterns from the training data such as edge or object part detectors, a prototype based network uses explicit features extracted from training examples to measure similarities between these features and the test sample which requires a decision. For the second aspect we identify which regions match between the test sample and the prototype examples relying on Layer-wise Relevance Propagation. For the third step we propose to use the prototype similarity scores for identifying outliers.
We compare performance in terms of the classification, explanation quality and outlier detection of our proposed network with baselines.
We show that our prototype-based networks deliver meaningful explanations and promising outlier detection results without compromising classification accuracy. The new method showed promising results on images of CT scans and stained cancer biopsies.

Read more: P. Chong, A. Binder et al., "Toward Scalable and Unified Example-Based Explanation and Outlier Detection," IEEE Transactions on Image Processing, 2021.

Learning from limited data: Unsupervised deep learning

Multi-view clustering refers to the process of automatically discovering groups of objects in a dataset, where the data from each object comes from multiple sources or views. Recent methods for multi-view clustering rely on deep neural networks to convert the original data to representations in which the groups are easier to find. It is often argued that it is beneficial for the representations to be aligned. This means that representations from different views corresponding to the same object, should be approximately equal. In this work, we analyze previous methods, and identify several potential drawbacks with the alignment requirement. We show that alignment can reduce the performance of the model, particularly in the presence of corrupt or noisy views that do not add any useful information about the data. We then leverage this new insight to design two new methods for multi-view clustering. These methods do not suffer from the problems of alignment, yet they achieve state-of-the-art performance on several challenging benchmark datasets.

Read more: D. Trosten, S. Løkse, R. Jenssen, M. Kampffmeyer, «Reconsidering Representation Alignment for Multi-view Clustering,» CVPR 2021.



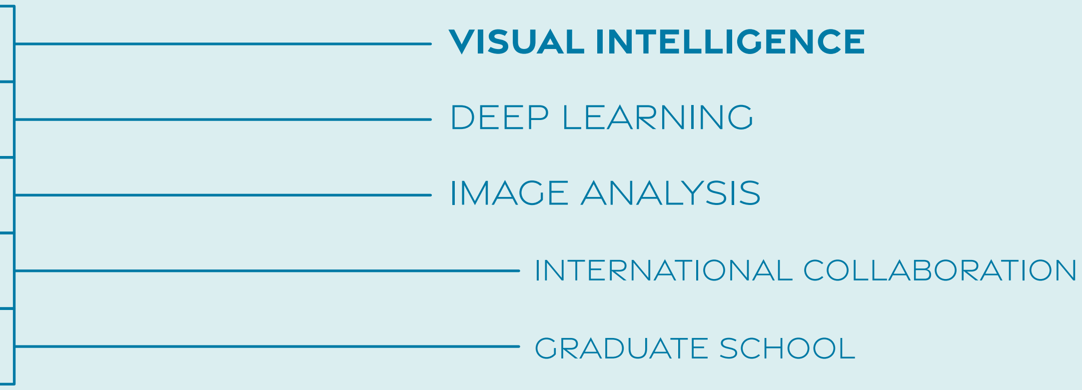


Illustration: Changkyu Choi & Torger Grytå.

Figure: The SDG colour wheel.

Visual Intelligence

Explainable deep learning for novel innovations across applications

Imaging of the unseen is needed in a large variety of applications for imaging of the inside of the body, the seawaters, the subsea and the earth from above. However, there is a lack of analysis tools with the power and trustworthiness to fully exploit such complex imagery for knowledge extraction, innovations, and reliable new technology.

The Visual Intelligence research partners, UiT – The Arctic University of Norway, the Norwegian Computing Center, and the University of Oslo (UiO), answer these challenges together with our strong consortium of industry and public sector partners.

We research the next generation deep learning innovations by creating synergies and cross-fertilization between application domains of utmost societal importance and that all depend on complex visual data for value creation within:

- medicine and health
- marine science
- energy
- earth observation

Our innovations rely on solving grand research challenges for developing explainable deep learning models, utilizing *limited training data* and generating *geometrically and physically plausible decisions* with associated *reliability and uncertainty quantification.*

Supporting the UN sustainability goals

Intelligence can contribute to several challenges and important issues addressed by the UN's sustainability goals.

The innovations in the field of medical image analysis contribute directly to ensuring healthy lives and as well as promoting wellbeing for all at all ages (goal 3) by obtaining more efficient tools for diagnosing heart disease and cancer. Our solutions for monitoring the marine environment and fisheries contribute to sustainable use of the oceans and marine resources (goal 14) while innovations for vegetation monitoring contribute to sustainable management of forests, land resources and biodiversity (goal 15). Improved solutions for interpreting the digital subsurface can greatly help ensure access to affordable, reliable, sustainable and modern energy (goal 7).

Shaping the future

In the age of digitalization and with the current AI revolution, there is a need for research-based competence in the Norwegian industry. Visual Intelligence will educate candidates being able to identify limitations of the technology, including when and where to use it, and when not to use it. Towards this end, we are dedicated to open science and transparent research.

Principal investigators:

Robert Jenssen (UiT)

co-PIs Anne Solberg (UiO)

Line Eikvil (NR)

INNOVATION AREA 1

Health and medicine

Background/Rationale

The innovations in the field of medical imaging aim at obtaining more efficient tools for diagnosis support and decision support for diseases such as heart disease and cancer through the use of deep learning technologies. One of the major obstacles for this is the availability of training data within this area. Another very important aspect, when moving into diagnosis, is estimation of confidence and uncertainty in the predictions as wells as explanation of predictions. Furthermore, increased robustness to shifts and changes in shifts in sensors, parameters and cohorts is important.

GE Vingmed Ultrasound wants to develop innovative products through increasingly more intelligent cardiac ultrasound scanners capable of assisting the user to increased productivity and accelerated decision making. This can give both improved diagnostic accuracy, and improved productivity by automating repetitive tasks.

The Norwegian Cancer Registry which is responsible for cancer screening in Norway, expect the demand for population-based screenings for more cancer forms to rise. For this to be feasible, reliable automatic or semi-automatic solutions are needed. This will also enable use of more data and systematic analyses for changes over time, to help in the fight against cancer.

UNN's main objective is to provide diagnosis and treatment at a high international level for the population in Northern Norway by developing deep learning methodology for novel medical image analysis. This is fundamental for paving the way for integration into clinical diagnosis support and decision support systems for enhanced patient treatment. Helse Nord IKT facilitates this for infrastructure and data retrieval.

Objectives

Performing objective measurements in ultrasound images

Measurements of dimensions, e.g. of left ventricle in two-dimensional echocardiography (2DE), can be highly significant markers of several cardiovascular diseases and such measurements are often used in clinical care. The location of positions needed for measurements is however challenging in ultrasound images due to fuzzy boundaries and varying reflection patterns between frames. This also leads to a large variability between observers, where effective automation may be an approach to reduce this variability. However, due to a need for expert annotations representing a variation of diagnoses and due to observer variability, training data are scarce and can be noisy. The aim is therefore to develop methods and approaches enabling training of deep networks from these limited annotations.

Imperfect image quality in cancer screening

In population-based screening programs a large number of individuals are examined yearly. In the Norwegian breast cancer screening program, about 250 000 women participate each year. Thus, a large number of images are taken across the country by different hospitals and by a large number of radiographers. When the mammograms are acquired small movements of the breast may result in reduced image quality that can be hard to detect for radiographers, but which can affect subsequent interpretation of mammograms. Hence, it is desirable to detect this already at acquisition time to ensure high-quality images, and if imperfections are still unavoidable to be able to reconstruct a perfect image. Challenges here are that the current manual interpretation process does not provide annotations of image quality, which means that training data are scarce.

Unlabeled features for cancer screening

Annotations from screening generally contain information on the level of suspicion of cancer. They may also, after confirmed diagnosis, contain information on cancer types and severity. There may however be other characteristics of the images that affect both the probability of there being cancer and the probability of being able to detect that cancer. In mammography such characteristics are typically related to type and density of tissue, but there may also be other factors. It is believed that identifying and having knowledge of such features can help to improve both manual and automatic cancer detection. Challenges are again that no annotations at this level exist.

Characterizing cancer from joint CT/PET/MR

Developing accurate deep learning systems for automatic detection of liver lesions, and in particular systems that can accurately differentiate between different types of liver tumors, is of great clinical importance. In Norway, around 11000 patient controls are performed per year for colorectal cancer and around 1400 patients develop liver metastases either during the treatment- or follow-up period. According to the Norwegian guidelines, patients who are treated for liver metastasis and all patients amenable for surgery, shall be controlled for five years after the treatment of liver metastasis with new CT imaging every six months.

Models that automatically can detect liver lesions from such CT images taken over time are lacking. This is mainly due to the fact that pixel-level annotations are difficult, costly and extremely time-consuming to obtain, which limits the use of completely supervised approaches to small datasets. Quantification of uncertainty in predictions and the need for explainable methods are of concern for this objective. At the same time, we are working to characterize other forms of cancer (e.g. lung cancer) from simultaneously obtained CT/PET/MR imagery and associated with this research on improving the imaging procedure itself based on deep learning is of great interest.

Cancer diagnosis via digitalized pathology

The objective is to improve the accuracy of cancer diagnostic particularly focusing on lung cancer, using deep learning to extract clinically significant information from whole-slide-images. This has the potential to increase diagnostic precision and to pave the way for implementation of automated tasks and to provide additional cancer characterization, thereby enabling pathologists to focus on the interpretation and clinical significance of the additional results. Whole-slide images (WSI) contain information about millions of cells. However, the size of the WSI and the need for detailed annotations limit the applicability of traditional supervised approaches.

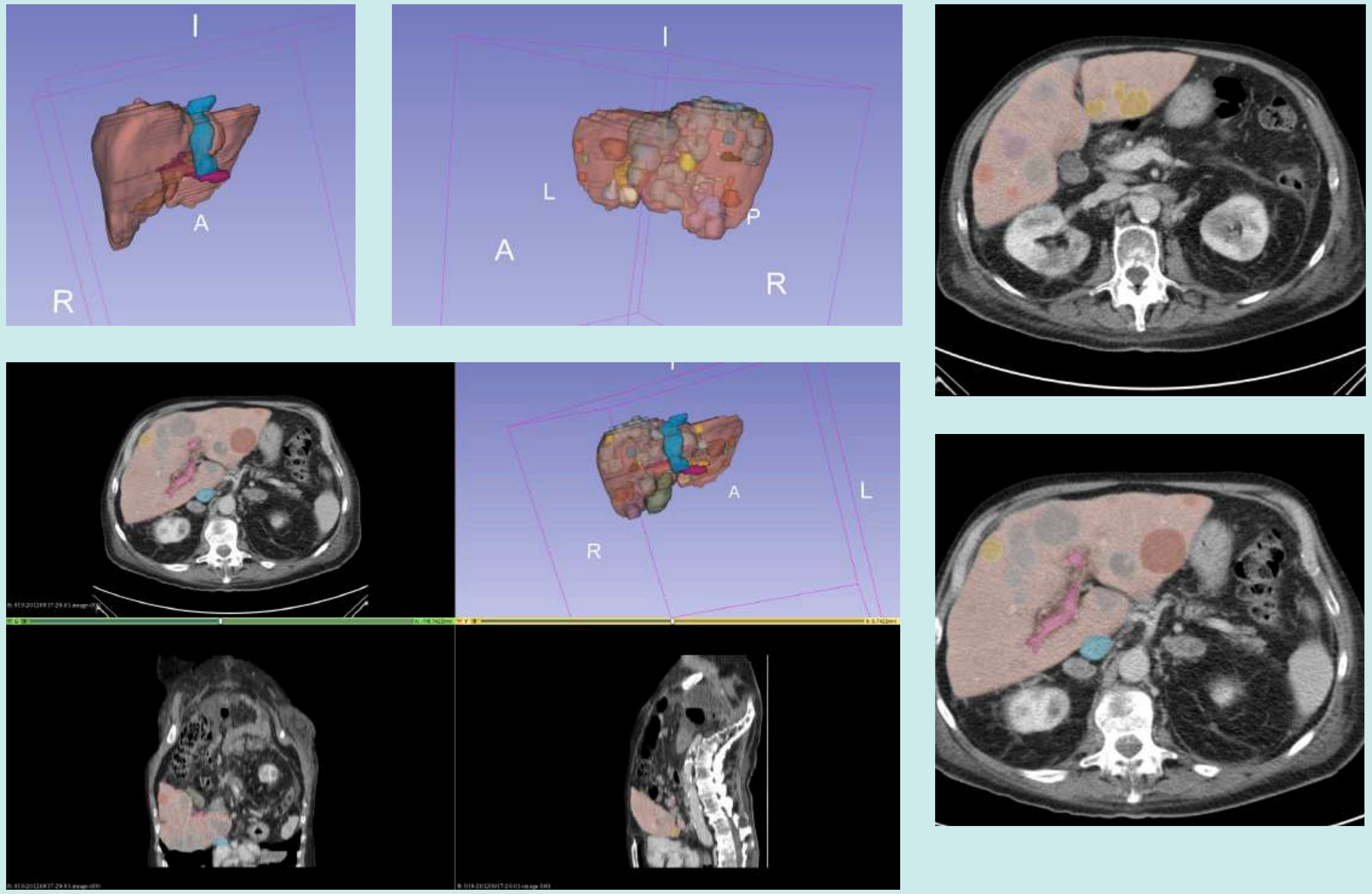
Our activities in 2021

In 2021, we worked on the problem of automatic measurements of dimensions of the left ventricle in two-dimensional echocardiography. Throughout 2021, a first approach based on graph convolutional networks (GCN) has been developed. This new approach enables incorporation of information on relative positioning when predicting landmarks needed to estimate dimensions and has in this respect showed an improvement over GEVU's existing approach. Still, the new method does not yet give an improvement in the measurement accuracy as such. We continue to further improve on this method to achieve this. Furthermore, GEVU plans to integrate the new method as a tool on their ultrasound scanner.

As we proceed we will consider exploitation of the temporal aspect and handling of differences between hospitals through domain adaptation. The use of the temporal aspect is related both to finding the best frames for measurements and exploitations of more information in the measurement predictions and will be considered in this context. The domain adaptation will aim at avoiding for differences in datasets between hospitals to lead to reduced performance for automated measurements. The first focus here will be on using state of the art techniques to analyze how domain shift effects the results of automated measurement algorithms in echocardiography and second on how domain adaptation techniques can be implemented to make model results more consistent when tested on data from different unseen distributions.

For the analysis of mammographic images, we worked in 2021 on the problem of detecting unlabeled features and with a special focus on features related to mammographic image quality. Image quality deficiencies can make it more difficult to interpret the mammograms, and important factors affecting the image quality have been identified as image blur, tissue density and breast positioning within the images. Initial analysis has been performed of the problems, data, data availability, and relevant literature, in addition to initial experiments on blur detection and exploitation and analysis of weak labels and gradient responses from models for mammogram classification. In the continued work there will also be a focus on automatic evaluation of the quality of image positioning, where this is related to optimal positioning of the specific parts of a breast within the image. This will involve landmark detection, as well as detection and evaluation of their relative positioning. The problem has some similarities to that of landmark detection in ultrasound images and can benefit from experiences made there.

Detection of liver metastasis relies on a provided dataset of CT scans from UNN which has been sorted, preprocessed, pruned, and structured for deep learning during 2021, after REK approval. We have set up a pipeline to enable clinicians from UNN to assist in the task of annotating and creating segmentation masks for the CT-volumes. We have set up a supervised segmentation baseline utilizing the U-Net architecture for segmentation of 2D-slices of the CT-volumes. The preliminary experiments show promising results. We are working on extending this to 3D to exploit the contextual information in the CT-modality. To leverage the vast amounts of unlabeled CT-images from UNN we have started exploring the possibility of self-supervised pre-training to improve the baseline but further investigation is needed. To leverage the radiology reports associated with the CT-scans we are working to extract key information from the free text that later will provide information in the form of weak labels to improve the segmentation. We continue the collaboration with UNN to annotate parts of the dataset, to use the annotations in combination with the weak labels from text to develop more powerful models that can detect lesions in the liver from CT-volumes.



Figures: Detection of liver metastasis from CT image volumes. Keyur Radia, UNN, and Eirik Østmo, UiT.

We attempt to achieve detection of liver metastasis by training a model to predict e.g. the estimated position or the total count of lesions described in the radiology report, with the aim of exploiting the temporal aspect of the CT-dataset i.e. that we have multiple scans of each patient. In 2021, we have also worked on preliminary studies related to characterization of other types of cancer based on PET/MR/CT or a combination of these, i.e multimodal analysis. Connected to this, we have instigated some new developments related to the PET-imaging procedure itself. Towards this end, we have developed a new method for deep learning derived arterial input-function estimation in dynamic positron emission tomography imaging, which has been submitted as a Disclosure of Invention (DOFI).

Related to digitalized pathology, we have in 2021 developed a model for quantifying and interactively analyzing tumor-infiltrating lymphocytes (TIL) as prospective biomarkers for clinical pathology. We used publicly available datasets with limited and noisy labels for cell types. We verified the model using our own unlabeled whole-slide image dataset by showing that the annotation produces by the model correlates with known disease outcomes (pseudo-labels), and by having two experienced pathologists evaluate the annotations. In the continuation, we will for instance work on reducing the computational complexity of the approach for instance in terms of the the inference code to reduce response time.

We have in 2021 set up quarterly planning meetings with Helse Nord IKT and personnel from UNN. Catalyst by this initiative, UNN has established a task force with members from UNN, Helse Nord IKT, SPKI, Visual Intelligence, and other relevant parties to establish protocols (guidelines) for research projects (including Visual Intelligence's) and implementation projects that need Helse Nord IKT to extract health data from UNN for their projects. A help desk is being set for communication with ICT personell (HN IKT) and data protection officers, among others, at UNN. The task force has in 2021 been writing consultation responses to government strategies on new legislation to facilitate safe data retrieval for AI projects.

Planning ahead for 2022 and beyond, UNN in collaboration with Helse Nord IKT, are continuing to plan protocols, write consultation responses and conduct data retrieval to obtain new medical image data sets for further research purposes. This includes PET/CT and PET/MR image data bases related to prostate cancer, rectal cancer and mammography image quality enhancement software (with input from the Cancer registry), and MR data bases related to brain scans.

Principal investigators:

Arnt-Børre Salberg (NR)

co-PIs Andreas Austeng (UiO)

Robert Jenssen (UiT/NR)

INNOVATION AREA 2

Marine sciences

Background/rationale

Efficient and reliable methods for automatic analysis of complex marine observation data are needed to ensure sustainable fisheries and harvest. The Institute for Marine Research (IMR) has a mission to be a leader in providing knowledge to ensure sustainable management of resources in our marine ecosystems. Their monitoring and research activities are to a large extent data driven, and efficient data analysis and processing pipelines are important to achieve their mission. They collect vast amounts of complex marine observation data containing valuable information needed to ensure sustainable fisheries and monitor the ecosystems. Manual analysis of these is a bottleneck, and automated solutions are needed for the next generation marine big data services. Image data may come from sources such as acoustic surveys, trawl images, subsea videos and underwater microscope videos.

Many of the challenges related to the use of deep learning in this area are related to training data, where the amount of annotations can be limited and the quality variable and it is too expensive to get more and/or better data. There is also a need for explainability and reliability, as trust becomes very important when the outputs from these systems are intended as input to models for abundance estimation which again is a basis for setting of fishing quotas.

Objectives

Detection of species from benthic images

Detection of specific species using different kinds of subsea imagery is important for IMR to estimate abundance and manage exploitation. Benthic images are currently taken from a towed platform acquiring images along the sea bottom, but image acquisition is in the process of being implemented on AUV's.
A challenge is that there is a limited number of annotations, and there will therefore be a need to train the models almost without labels. Furthermore, as results are to go into IMR's advisory processes, there is a need to provide reliable confidence and uncertainty measures.

Individual recognition (re-identification) of species from underwater video

Surveillance of individual fish is important for IMR to observe and survey fish behaviour and responses. With the aim of potentially replacing current use of physical tags (RFID) for this task, automatic visual identification of individuals in a wild fish population is desirable. To obtain this, problems like detection, tracking and identification of fish across frames and image sequences will need to be solved. This will call for approaches for learning from limited data. Furthermore, high precision and reliability is needed to replace physical tags. Hence, it will be important to provide confidence and uncertainty measures.

Arnt-Børre Salberg presenting at the Visual Intelligence days. Photo: Robert Jenssen.

Detection of sea mammals from aerial imagery

Abundance estimation of sea mammals like ice breeding seals (harp and hooded) and coastal seals (grey and harbour) are based on aerial photographic surveys. Automation of this process will achieve cost-effective abundance estimation of seal populations that can lead to better long-term management of seal populations. Previous activities have demonstrated that there is a potential in using deep learning for this. However, highly imbalanced species distributions and shifts in sensors and conditions over time are challenges that need to be solved.

Detection and classification of fish species from acoustic data

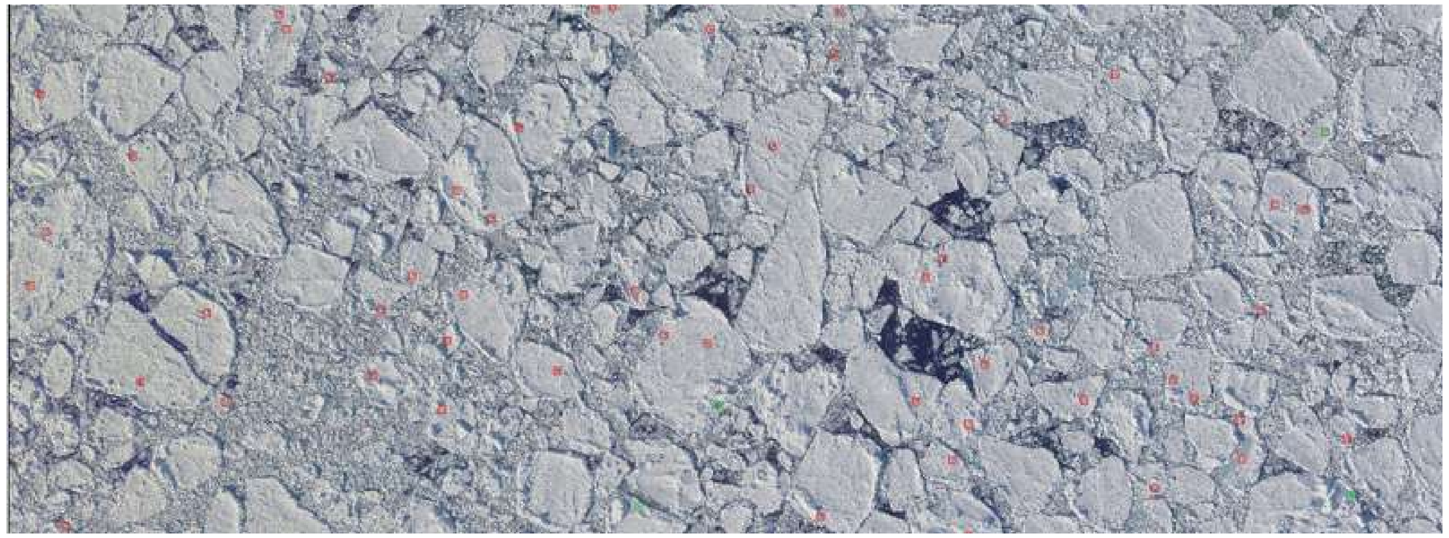
Acoustic data from echo sounders and sonars are used as input to stock assessment in fisheries management models. The data are typically semi-automatically or manually annotated. The volume of annotations is large, but the quality is variable and the annotations are not suited for direct use for training deep learning models. Furthermore, characteristics of surveys and equipment may change over time. Finally, there will also be auxiliary information available from the surveys that can provide useful information. For future use in stock assessment important issues are also challenges related to providing confidence and uncertainty measures and providing explainability and reliability. Solutions will also need to enable prototyping at IMR, where predictions will be tested for use in abundance assessment.

Our activities in 2021

Discussions around the task on detection of species from benthic images have started. The identified task will address the detection of snow crab, where results are useful in IMR's advisory processes towards snow crab management. IMR are currently in the process of acquiring benthic imagery from a new type of UAV platform. It is expected that the new images are quite different from the existing benthic imagery. Hence, method development for this task will wait until new imagery are available.

An activity on recognition/re-identification of corkwing wrasse from underwater video has been started. Initial work has been done on combining video-footage of corkwing wrasse nests with RFID signals from fish simultaneously monitored by RFID antennas, to obtain a correspondence between tagged individuals and the fish appearing in the images. This includes preliminary models for detecting and tracking corkwing wrasse, while potential models for re-identification have also been suggested. Still, much research remains to fully solve this, and there will also be a need to handle both new videos of unseen fish and to be able to incorporate new and unseen individuals/classes to be identified as they appear, and over time also handle non-constant classes as fish grow and mature.

For the detection and classification of seals on ice, several activities were initiated in 2021 and which will be followed up in 2022. A detection pipeline for detecting, localizing, and classifying seal pups resting on ice was developed. The deep learning model was based on a Cascade R-CNN object detection module, with a ResNest-101 backbone. Each detected seal pup is classified into the species harp and hooded seal. The model was trained on data acquired on surveys in Canada 2008, 2012 and West Ice 2007, 2012 and 2018. It was tested and evaluated on data from Canada 2017. Even though the model is working very well, it suffers from highly imbalanced class distributions, with harp seals far more abundant than hooded seals in the training data. Some images also cause a high false detection rate. In the continuation, our work will be focused on improving the performance by handling the class imbalance by adjusting the sampling scheme so that both harp and hooded seals are represented in each mini-batch, and by exploiting the fact that the different seal species often do not mix. To handle the dataset shift between different surveys, self-supervised learning approaches are being investigated. Moreover, we will evaluate the pipeline on new survey data.



Photo/Illustration: Institute of Marine Research/Arnt-Børre Salberg, NR.

For acoustic data, early work had investigated models for supervised semantic segmentation of sandeel from acoustic data. Continued work on this, in combination with Cogmar and SFI Crimac, has further extended these models to incorporate auxiliary data on sample frequency and depth into the models. A journal paper describing the extended model and improved results has been submitted. IMR have also started integrating these models in their pipeline for abundance estimation. Further work on this will now be focused on developing segmentation methods that can learn from weak labels. This will be important to enable handling of more species, where annotations do not come as bounding boxes for fish schools, but rather as percentages of fish species within larger regions of the echograms. In addition, research on approaches for exploitation of more and other types of auxiliary information will continue. Now with a special focus on how to include and exploit information coming from trawl samples that are close in time and location to the acquired echograms.

In combination with the Cogmar project, a semi-supervised approach for semantic segmentation of sand eel has been developed. In particular, we developed a semi-supervised approach for classification of acoustic image patches, where the main idea is to exploit vast amounts of unannotated data in addition to some annotated data. This work was published in 2021and a follow-up work on semi-supervised acoustic image segmentation is submitted. Plans are now for IMR to test and evaluate the approach in their context of abundance estimation and integrate it into their process. These tools will help to reduce the dependency on large amounts of annotated data to better deal with an increasing volume of datasets that may present both new characteristics and new species. Further work on the semi-supervised segmentation is now planned to focus on developing interpretatability methodology for analysis of the models. This can help identify potential vulnerabilities of a model and thereby improve its accuracy and reliability. Such interpretation may also be of interest for the supervised models and for comparison of strengths and weaknesses between the supervised and semi-supervised models and to evaluate this in the context of traditional fish school classification models.

Principal investigators:

Anders U. Waldeland (NR)

co-PIs Anne Solberg (UiO)

Benjamin Ricaud (UiT)

INNOVATION AREA 3

Energy

Background/rationale

The innovations in this area focus on robust and reliable methods for automatic analysis of complex imagery from the digital subsurface for more efficient and detailed oil and gas exploration. Equinor has a major goal of becoming more data-driven and maximizing the value of the vast amount of data available, especially on the Norwegian Continental Shelf. A part of this includes challenges related to analysis of the digital subsurface, e.g., in the form of seismic and bore-hole imagery, which is important for oil and gas exploration. Automated analysis of these data can lead to large savings in time and resources and more efficient and precise exploration.

The amount and quality of labelled training data is a challenge in this field. Existing interpretations are not made for machine learning purposes. Hence, the annotation quality for the task is unknown and interpretations are generally incomplete. Generating realistic simulated data is difficult as simulated data tends to be too simple. For many of these problems context and dependencies, through exploitation of prior knowledge of the geology, dependencies in space and time or results derived from existing solutions could improve predictions.

Objectives

Model continuity in seismic data

Seismic data image the geology of the subsurface represented as a 3D cube. Hence, it is a representation of continuous surfaces and objects in 3D. It is desirable to find models that can exploit this type of contextual information and establish continuity in 2- and 3D. This type of information could be useful for seismic interpretation both as possible input to manual and more automated processes.

Detection of data constrained areas

Some phenomena observed in the subsurface can be quite limited in size but may still be important to detect accurately. One class of such phenomena are points and lines where geologic structures end through truncations or by lapping on to other structures (truncations, downlaps, onlaps). These can also be seen as points/lines of discontinuity. Because such areas are limited in size, potential training samples will be few. Furthermore, these are phenomena that are not actually marked explicitly in a process of manual interpretation.

Models based on less training data

Tools for automatic seismic interpretation are most useful when new areas are to be surveyed. This means that training data will be limited, while the geology will often be different from other geographic regions. Manual labeling is costly and reduces the gain of automatic interpretation, and it is also time-consuming to train networks. An interesting question is therefore whether there can be a more general way to improve on this. Can we better understand how various training data influence a network to select less and better training data, or can we derive networks that can work with much less training data.

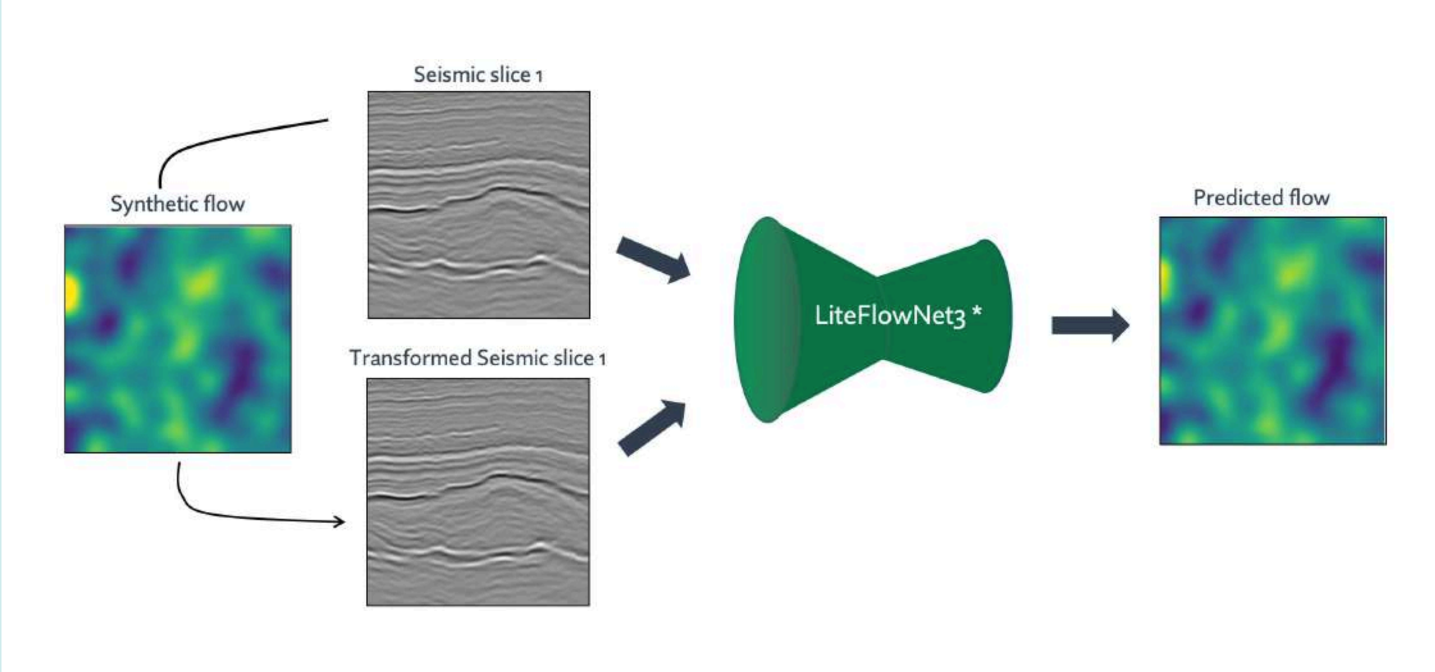


Figure: The proposed method is trained on synthetically deformed (real) seismic data. Anders U. Waldeland, NR.

Our activities in 2021

An initial activity building on approaches from the optical flow literature has been started on modelling continuity. This has been tested on unlabeled seismic to evaluate the potential both for describing continuity, horizon tracking and detecting discontinuities. The method gives improved results compared to traditional slope estimation methods and works fully unsupervised. So far, however, it does not obtain sufficiently accurate results for further use in the geoscientists workflow.

In 2021, we have started the discussion on recognition and detection of data constrained phenomena. Such phenomena can be specific events and formations in the geology that are of particular interest, such as unconformities, truncations or depositions. Typically, these occur quite infrequently, and training data are very limited. Different avenues of research will be explored in the continuation, including content-based image retrieval, unsupervised feature learning and self-supervised representation learning. This work will continue into 2022.

Principal investigators:

Andrea Marinoni (UiT)

co-PIs Anne Solberg (UiO)

Rune Solberg (NR)

INNOVATION AREA 4

Earth observation

Background/rationale

Optical images from drones or satellites and data captured by lidar and radar sensors from above contain enormous amounts of complex data. They have the potential to reveal valuable information about our planet and its surface that could be used to automate terrain mapping or to detect objects and hazard risks such as vessels and potential oil spills at sea.

Objectives

New methods for automatic change detection in aerial images

When updating an existing map database, the most time-consuming task is to detect changes (new buildings, new roads, etc.) and to determine an accurate outline of the objects to be mapped. Today, this is done semi-automatically using aerial images and photogrammetry or airborne laser scanners and analyzing laser-return point clouds. The goal of this work is to detect changes automatically by using deep learning.

New approaches for object detection from an airborne camera system

For inspecting infrastructure like powerlines and technical objects related to such, data are often acquired by using a helicopter rig with several cameras and a LIDAR system. The cameras are triggered at a fixed time interval. As a result of this, only a limited number of images contains objects of interest. The goal is to use deep learning to detect interesting objects automatically, such as technical installations that may need maintenance.

New algorithms for vessel and object detection

Challenges related to the detection of small object sizes encompass multiple clutter distributions, imbalanced classes, as well as the issue of noisy labels and low resolution. Moreover, it is of paramount relevance - especially for operational scenarios - to provide a quantification of the confidence that can be associated with the outcomes produced by object detection platforms. For these reasons, research on new deep learning approaches to address these points is necessary. Specifically, the results of these schemes can help in detecting small objects in water areas, as well as tracking vessels from harbor to open water, possibly combining multiple sensors (e.g., remote sensing data and AIS records) to improve the precision of the methods.

Oil-spill detection and thickness characterization

When addressing oil spill characterization, challenges are related to the scarcity of high-quality training data, a lack of large-scale annotated datasets, and difficulties related to the extraction of reliable information from heterogeneous datasets with different geometrical and statistical distributions as well as multiple spatial and spectral resolutions. It is crucial to develop new frameworks for data analysis that are able to tackle these issues, to provide reliable and accurate information on the detected oil spills. Deep learning can hence play a key role in this sense, so to provide robust and efficient characterization of the oil properties in the ocean.

Photos: Aerial images and outlines (in yellow) of buildings in the Follo region. Left: Aerial image from 2018 and outlines used as 'ground truth'. Right: Aerial image of 2020 with automatically detected buildings. Notice the new building on the righthand side (with a bright ground surface around). (Terratec/NR).

Our activities in 2021

We have facilitated research on object and vessel detection as well as taking some first steps towards oil-spill detection. KSAT has spent considerable efforts to set up work-spaces suitable for machine learning, massive storage and massively parallel batch-processing infrastructure capable of meeting any compute or data demand in a much shorter time than possible before. All of this is set up with role-based access control, enabling close collaboration by permitting external contributors access to anything they need in a much more timely manner. This will enable students to work in collaboration with KSAT and is a critical infrastructure for the benefit of the PhD projects and other collaborations. This is important, since for vessel and object detection from satellites, we will exploit available labelled training data that have been collected over time by KSAT operators through the manual quality assurance procedures in their in-house-semi-automated ship detection services. Our research activities will target the training of neural networks under the constraint of limited training data.
For instance, a master student project at UiT set out to compare the new deep learning approach called YOLOF, a single-stage object detection model, to KSAT's existing multi-stage vessel detection solution.

For oil-spill detection, semi-supervised deep learning networks for multimodal remote sensing data analysis will be developed over time so to fully exploit the available training data and to robustly infer information on oil spill properties from high-resolution datasets to low-resolution scenes. We will seek to develop solutions that may embed information related to the physical processes in order to conduct the analysis.
In 2021, KSAT's summer internship programme set up a procedure for clustering oil spills with shared origin to identify so-called seep sites, which were then compared to infrastructure locations to categorize into natural and man-made origin. This activity enhanced the KSAT oil spill data archive in preparation for later research activities to commence.

When using aerial images to update an existing map database, the most time-consuming task is to detect changes (new buildings, new roads, etc.). In 2021, Terratec and NR collaborated on development of methodology to detect changes in images for updating maps of buildings. The objective was restricted to determine whether new buildings had been set up, or whether buildings had been demolished. Terratec prepared two datasets consisting of aerial imagery from 2018 with corresponding vector maps of buildings for the Follo region south of Oslo, and a similar dataset based on imagery from 2020. NR tested and tailored various approaches using deep learning for robust detection of changes. The results based on the best-performing methodology are currently being evaluated by Terratec. The current plan is to complete the prototype methodology in winter 2022 after final tuning and a large-scale test. Terratec then plans to integrate the method in their processing environment for operational testing. Successful use of the method will substantially improve the capacity of operators doing map revision as she/he can then focus only on the difficult cases and skip checking thousands of buildings where no changes have taken place.

For inspecting structures like power lines, data is often acquired by a helicopter rig with several cameras, and a lidar system. The cameras are triggered at a fixed time-interval. As a result of this, only a limited number of images contains objects of interest. The goal is to use deep learning to detect interesting objects automatically. Terratec is currently compiling and preparing a dataset for development by NR. As this also requires feedback from users – which objects are they interested in – it takes time to establish reference data ("ground truth"). We expect this dataset to be available soon.

Principal investigators:

Michael Kampffmeyer (UiT/NR)

co-PIs Anne Solberg (UiO)

Line Eikvil (NR)

RESEARCH CHALLENGE 1

Learning from limited data

Background/rationale

For real-life applications with complex image data, training data will often be limited, in the sense that annotations (labels) are sparse, even if the amount of acquired data may be vast. Annotations may also be incomplete and inconsistent (noisy) and they are generally made for other purposes than training machine learning algorithms and may be less suited for that purpose. Moreover, the data characteristics, are often very different from the standard images, making the current transfer learning go-to solution based on pre-trained ImageNet models infeasible because the image data of interest is statistically out-of-distribution with respect to the base model.

Objective

Learning from limited training data in order to exploit weak, noisy and incompletely labelled data is a research area that is stressed by a majority of the user partners as an immediate need. We therefore focus much on this in the early phase of Visual Intelligence.

Specific topics within this field that are highlighted by user partners as particularly important across the innovation areas are: domain shift/adaptation; weak labels; semi-supervised learning; one-shot/few-shot learning; simulated data and imbalanced categories.

Our activities in 2021

In the past year, we have mapped the immediate needs for methodology development within this research challenge at the user partners by organizing a specially tailored workshop for this purpose. Based on this, there is a clear need for learning from limited data across all innovation areas, with a large potential for cross-innovation synergies. Specific needs include methodology to utilize unlabeled data and weak labels as well as to design approaches that generalize to new classes based on a few examples (few-shot learning) and domain adaptation.

In our activities, we therefore have set up research activities to develop generic methodology development along the following directions:

- semi-supervised and unsupervised learning
- weak labels
- few-shot learning
- self-supervised learning
- domain adaptation

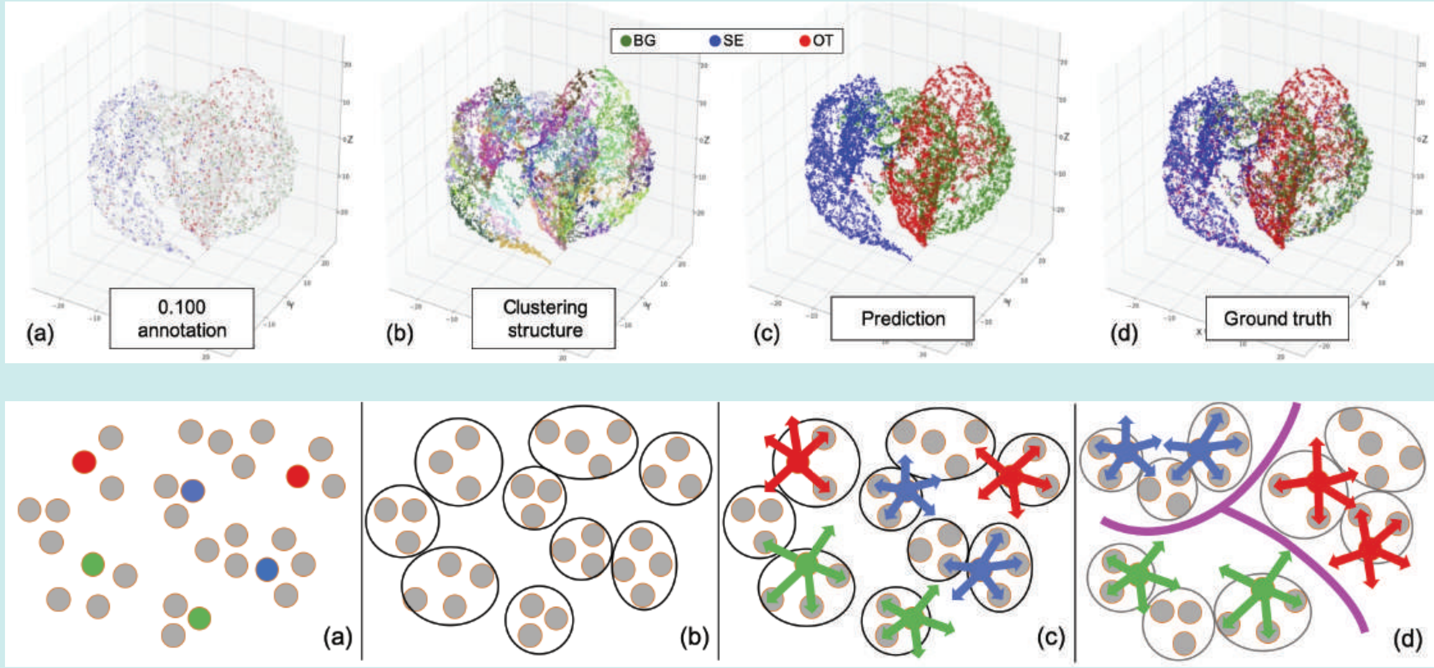


Figure: Semi-supervised fish detection leverages vast amounts of unlabeled images. Changkyu Choi, UiT.

For semi-supervised learning, we have in 2021 obtained initial promising results within Innovation area "Marine sciences". Here, we have developed methods for exploiting pseudo-labels for acoustic target classification. This has been done in close collaboration with the Institute of Marine Research and the methods have been tested on their data. This led to a published paper, leveraging also associated projects Cogmar and SFI Crimac (see "Research highlights" and "Associated projects). We will continue developing the methodology for segmentation of acoustic imagery. We see a potential for translating these methodological advancements to other user partner applications.

We have also worked on generic methodology for completely unsupervised deep learning, in synergy with associated projects DEEPehr and MedEx. Towards that end, we investigated novel solutions for incorporating information about objects in the form of multiple but different types of images for each object in an unsupervised manner for clustering the objects (multi-view deep clustering). The idea is to exploit available information in a better way. If for instance objects are imaged from different incidence angles, creating several images for the same object, then more information is potentially available for exploitation as opposed to using only one image based on just one angle. This requires new deep learning methodology for incorporating such information. Works along these lines were published in CVPR and in the journal Machine Learning. We are currently working on testing these new frameworks within the Visual Intelligence innovation areas.

Work has now also started on how to exploit so-called weak labels. Weak labels could for instance refer to situations where one has no access to ground truth annotations on a pixel level, but where additional information may be available for instance providing knowledge about the number of objects present in the images. This is particularly relevant for the health and medicine innovation area, where weak labels could arise from e.g. radiology reports, but weak label learning is also planned e.g within the marine science innovation area.

In few shot-segmentation the goal is to be able to do segmentation by learning from just a few images.
As an approach to this we want to exploit the fact that the foreground class often tends to be more homogeneous than the background. Based on this assumption we will investigate the use of anomaly detection inspired approaches for this problem. We have obtained some initial and promising results. Further, innovation area-specific self-supervised learning approaches will be explored, both to address few-shot learning and beyond.

For domain adaptation, we are in the process of evaluating robustness of deep learning solutions by exploiting the group structure in the data and exploring information-theoretic discrepancy measures between domains or shifted distributions. In particular, some initial investigations will be conducted on cardiac ultrasound imagery from GE Vingmed Ultrasound, first, in order to investigate potential domain shifts between cardiac ultrasound recordings from different hospitals.

Principal investigators:

Anne Solberg (UiO)

co-PIs Benjamin Ricaud (UiT)

Arnt-Børre Salberg (NR)

RESEARCH CHALLENGE 2

Context and dependencies

Background/rationale

Current deep learning systems for image analysis depend on individual pixel information, capturing dependencies solely via the convolution neighbourhood. This means that the ability to incorporate context and prior knowledge, e.g. about topology or boundaries, is limited. The ability to conform to physical models, and principles governing the image data generation and its properties is also limited, including modelling of spatial and temporal dependencies and processes. In most applications, additional expert knowledge is available but not expressed in a form understandable by a machine. Moreover, in some applications, additional data could be incorporated in the learning process. These data may come from other sources and be related indirectly to the learning task.

Objectives

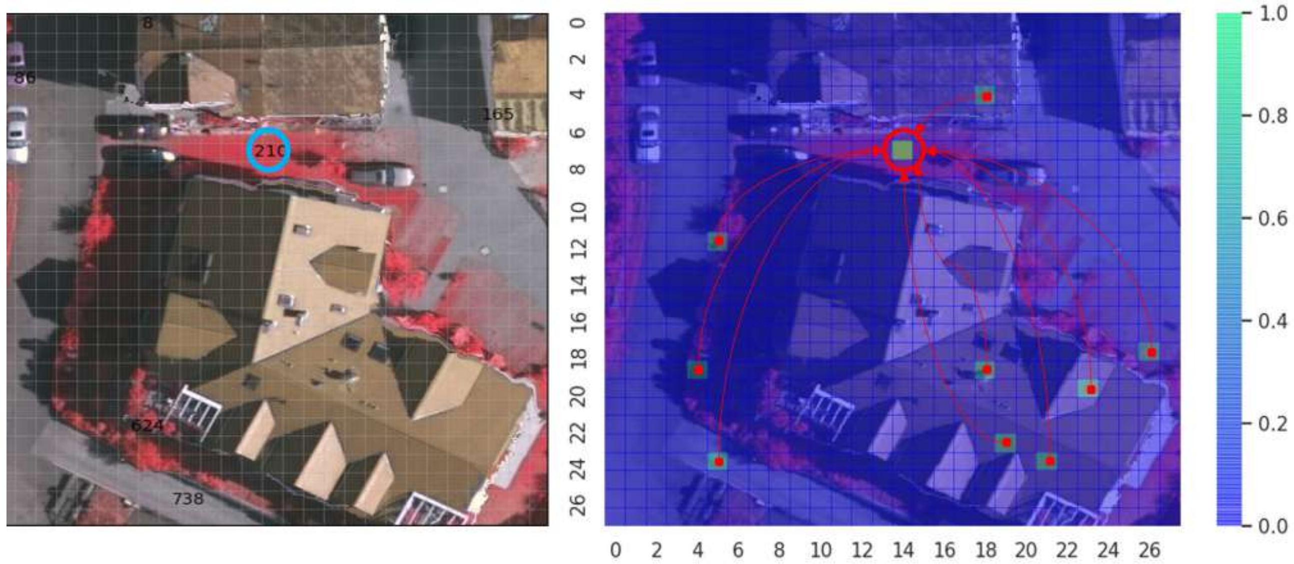
The objectives are to propose and design new innovative ways for including expert knowledge as well as additional data in deep learning systems.

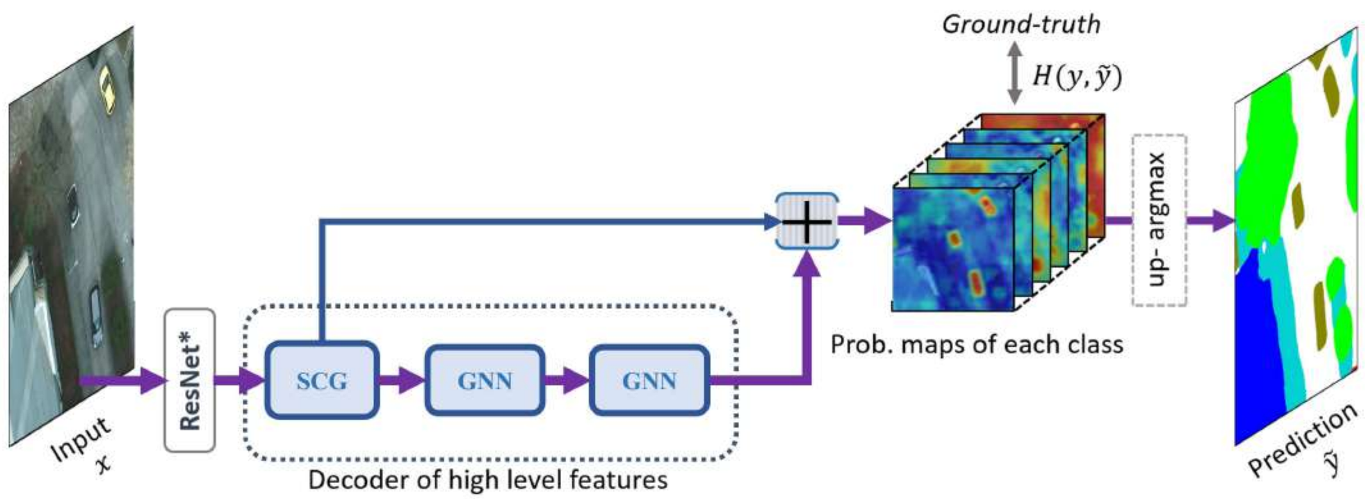
Our activities in 2021

Identifying the most important knowledge to include in the models is an ongoing work for each innovation area and particular application. It is clear that incorporating relevant knowledge and context are important for all innovation areas, but the type of knowledge/context varies a bit between applications.

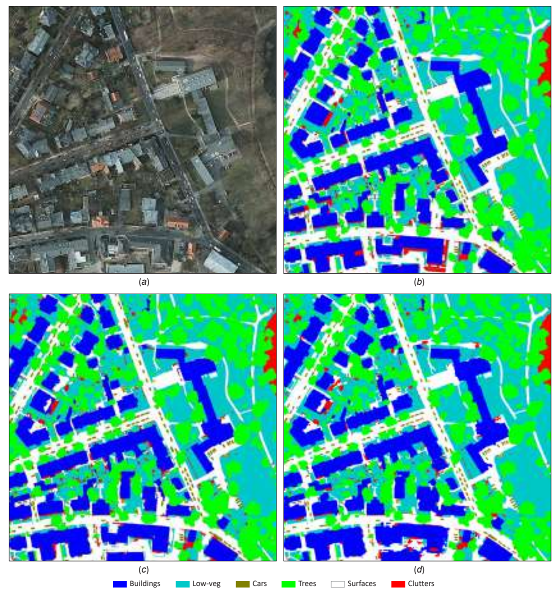
Initial work on using graph convolutional networks (GCN) for landmark detection in ultrasound imaging was started in 2021, and this work will be continued. We also plan to develop GCNs to be applied in on user partner applications in remote sensing, where it has a potential both for oil slick segmentation and segmentation of aerial images. In 2021, we developed several generic deep learning methodologies towards that end, in combination with associated projects. In one line of work, we developed a so-called self-constructing GCN to model long-range pixel dependencies for semantic segmentation of remote sensing images (published in the International Journal of Remote Sensing). In another line of work, we developed a deep learning-based procedure to assess changes in land cover by leveraging generative networks (published in the IEEE Transactions on Geoscience and Remote Sensing). For this research challenge, on how to incorporate context and dependencies in deep learning models, measures to quantify statistical dependencies are often needed. In 2021, we developed a new method for quantifying dependencies which is especially suited for deep learning. This work was published in AAAI.

In the continuation, we plan to continue generic methodology development on how to couple knowledge with models. Several approaches will be explored, but particular directions will be on graph neural networks and more general methods from geometric learning. These approaches have the potential for use in several innovation areas.





Figures: Incorporating context and dependencies greatly aid segmentation of remote sensing images. Brian Liu, NR.



Principal investigators:

Fred Godtliebsen (UiT)

co-PIs Anne Solberg (UiO)

Alba Ordonez (NR)

RESEARCH CHALLENGE 3

Confidence and uncertainty

Background/rationale

For safety-critical applications, e.g. in health, a limitation of current deep learning systems is that they are in general not designed to recognize when their predictions may be wrong or to recognize with some certainty that the input is inside the range of which the system is expected to safely perform. Simple regularization techniques such as the so-called dropout provide measures of variability, but not a statistically sound quantification of uncertainty propagating from input to output. Bayesian deep models are emerging, but have so far been challenging to develop for complex image data due to the complexity of the input data and the nonlinear nature of the data processing.

Objectives

Two main objectives within this research challenge are important. The first is development of methods for detection of out-of-distribution/outliers. The second objective is to develop methods for quantification of uncertainties associated with a trained network. This should include uncertainty estimates for the weights and in the predictions of a trained network. The uncertainties of the predictions will be used to develop confidence measures.

Activities

As reflected in the objectives and activities described for the innovation areas, deep learning solutions with built-in measures of confidence and uncertainties are identified as important by most user partners. It is expected that it will take some time until data sets useful for uncertainty prediction are available. Since the topic is challenging and good methods do not exist, we will start with more generic fundamental research on the topic.

Uncertainty for neural networks can be related to both the network model and the data or labels input to the model. Our aim is to address all these types of uncertainty. The work in 2021 which is continued in 2022 initiate research on these topics, but it is likely that it will take a few years to get solutions for all of them. We will divide our research in two major categories: simple, shallow networks for which Bayesian inference is feasible and more ad-hoc solutions suitable for deep convolutional networks.

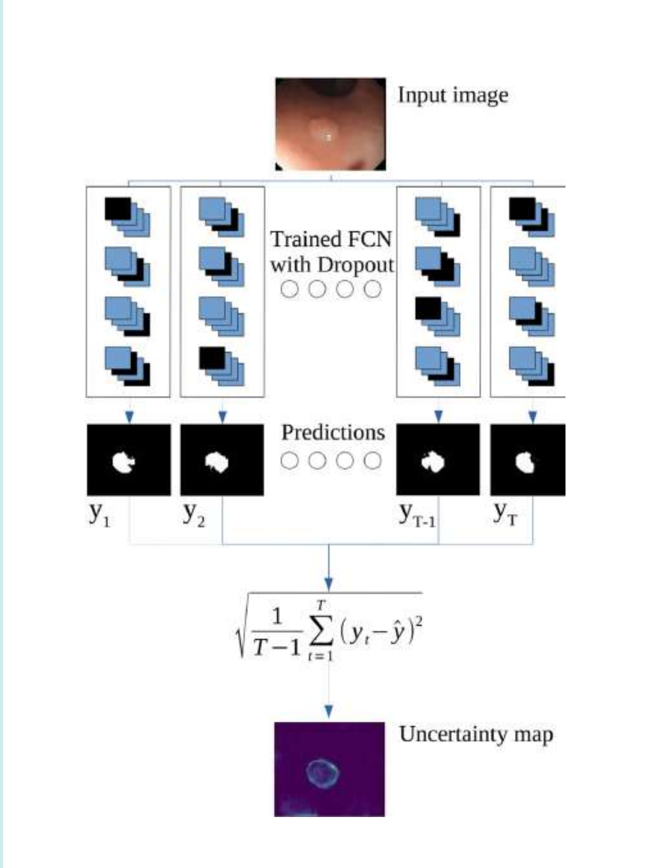
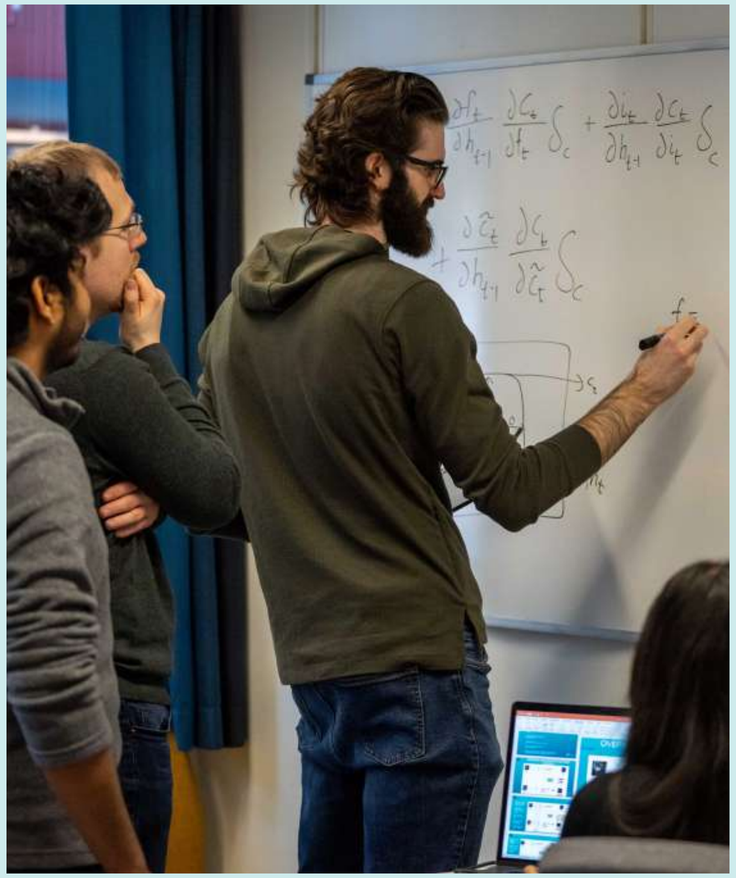


Figure: Uncertainty in deep learning systems captured by ensemble models. Kristoffer Wickstrøm, UiT.



PhD students Durgesh Singh, Jørgen Lund and Theodor Ross. Photo: Knut Jenssen.

The research performed so far has revealed that research in the following areas is crucial:

- Uncertainty in labels
- Uncertainty in input
- Integration of uncertainty at all stages
- Under-specified systems (many parameters to train)
- Many possible models/architectures
- Lack of stability (e.g. uncertainty due to different seeds)
- External settings (weather etc)

In 2021 two activities were initiated: using reversible jumps in Bayesian networks, and introducing uncertainty in a pretrained network using a new stochastic target MCMC-method.

Both of these activities will be continued in 2022 with the aim of publications. An important activity in 2022 will be to work on a comparative review paper on uncertainty/confidence. The focus in this paper will be a comparison of uncertainty estimates produced by a chosen number of methodologies on several different use cases.

In the latter part of 2021, efforts have been made to define a PhD project where characterization of the subsurface from seismic imagery may be developed within the context of uncertainty in deep learning, as a starting point, and these efforts will continue in 2022.

Principal investigators:

Alexander Binder (UiO)

co-PIs Shujian Yu (UiT)

Alba Ordonez (NR)

RESEARCH CHALLENGE 4

Reliability and interpretability

Objectives

The overall objective is to develop deep learning models with built-in robustness to data domain shift or artefacts and that offers a high-level explainability to aid improvement of existing methods.

Background/rationale

At the Visual Intelligence Days 2021, several aspects were mentioned from user partners related to this research challenge.

SFI user partners brought up a need to have a selection of methods available to evaluate the quality of predictors and their explanations; The need to ensure methods from explainable AI to be practically usable for the improvement of existing models; i) A need for research on explainability for example to counter data confounders or artefacts; ii) A need to be able to quantify uncertainty of the attributed importance provided by deep learning explainability models, which when applied to images often focus solely on attributing varying degrees of importance to regions of the image without considering whether the explanations may be questionable (uncertain).

Our activities in 2021

In 2021, a targeted workshop was organized in order to map needs with respect to explainability and reliability from user partners. This was also discussed at the Visual Intelligence Days, as mentioned above.

On development on generic development of interpretable deep learning, we initiated research in several directions in relation to associated projects, such as DEEPehr. We followed several directions. The first two directions followed the goal of using explanations to improve models.

In the first direction, we analyzed the efficiency of explainable models for breast cancer profiling including the prediction of quantiles of molecular properties in patient cohorts under very small sample size limits. This work was published under the title "Morphological and molecular breast cancer profiling through explainable machine learning" in the journal Nature Machine Intelligence (see also "Research highlights").

The second direction aimed at improving trained deep learning models by using novel model pruning procedures. Model pruning is an approach to shrink trained models while aiming at preserving their original prediction accuracy. To this end we devised a pruning based on explanation scores for every channel in a neural network layer. This work was published under the title "Pruning by explaining: A novel criterion for deep neural network pruning" in the journal Pattern Recognition.

In a third direction we aimed at unifying so-called prototype-based and example-based explanation methods in a teacher-student framework so that one can convert conventional deep models into prototype-based deep models. This results in explanations which provide you the nearest training prototypes for a given test sample and which highlight at the same time which parts of a prototype and which parts of a test example contribute to a prediction. Furthermore we proposed to use the prototype weights for a given sample in statistics for outlier detection. Effectively this provides two types of explanations and outlier detection. This novel work was published under the title "Towards Scalable and Unified Example-based Explanation and Outlier Detection" in the journal Transactions in Image Processing.

The final direction aimed at analyzing and explaining the predictions of models with multi-modal in and outputs. We illustrated the new ideas on image captioning, which is important e.g. in the medical field. We were able to devise an explanation-guided fine-tuning procedure which improves the prediction of sentences with rare input examples. This work was published under the title "Explain and improve: LRP-inference fine-tuning for image captioning models" in the journal Information Fusion.

We also conducted preliminary work by combining approximate Bayesian inference, and a gradient-based attribution method for explaining the decisions of a deep learning model trained to detect malignant breast cancer, we could (i) illustrate how to get uncertainty in model explanations, (ii) better understand when the model agreed with the doctor based on a quantitative study, and (iii) explore how to visualize the results in a useful way for the doctor. This work was submitted for the Northern Lights Deep Learning Conference (NLDL 2022).

We further initiated work on so-called self-explainable prototypical models. This novel approach was tested preliminary on publicly available chest X-ray images in order to detect whether prediction results were influenced by artefacts in the data resulting from the X-ray images being gathered from different hospitals (confounding factors) and to achieve this by explainability analysis. Such analysis is important in many image analysis applications. This work was submitted to the International Symposium on Biomedical Imaging (ISBI 2022).

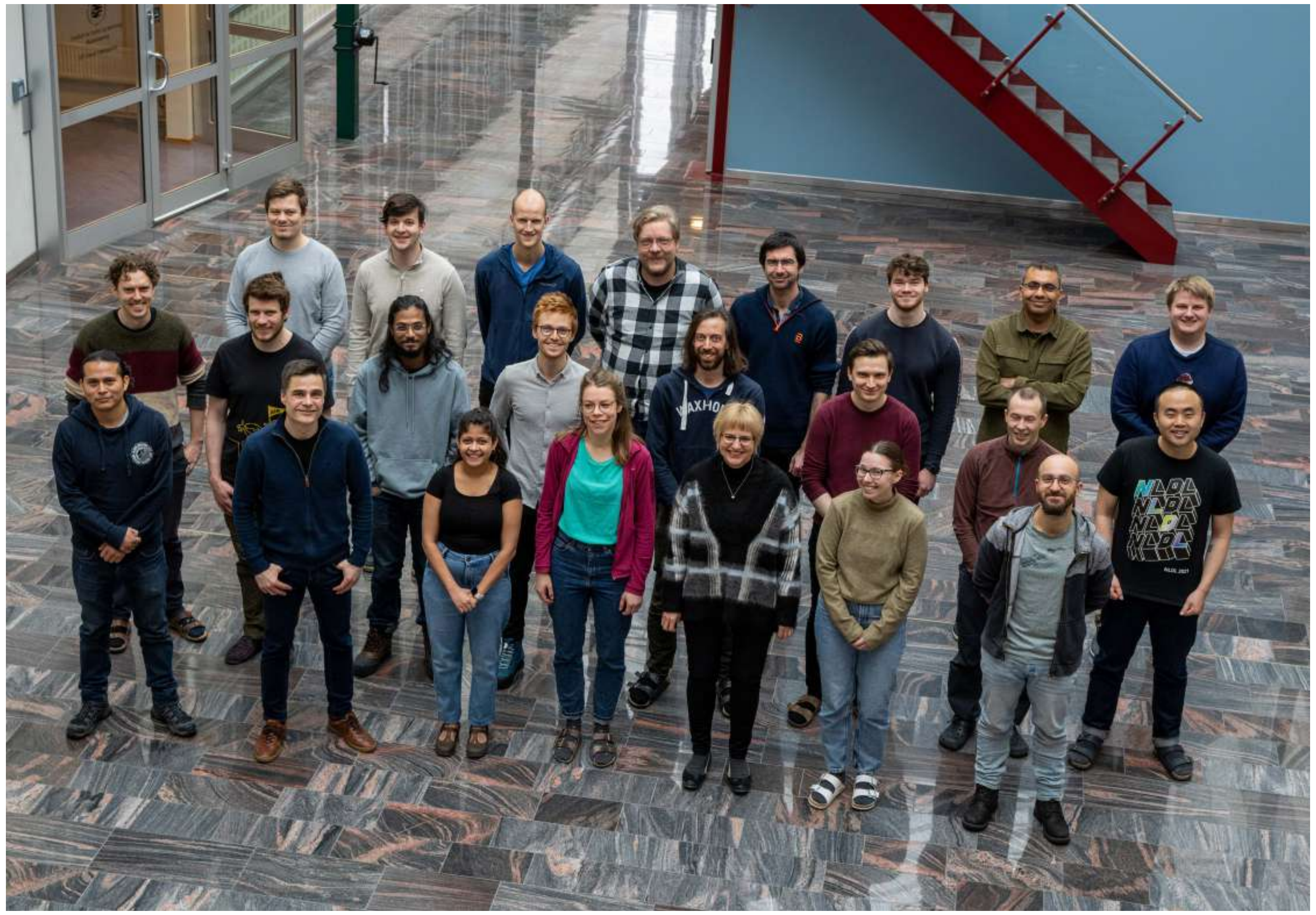
We will continue to pursue these lines of research and continue generic methodology development along the following broad directions:

- Evaluation of reliability of axiomatic approaches to measuring the quality of attributions of deep neural networks
- Approaches for the improvement of models using explainability methods
- Detection of data artefacts and confounders using explainability methods
- Towards guidelines for the estimation and representation of uncertainty of attributed importance

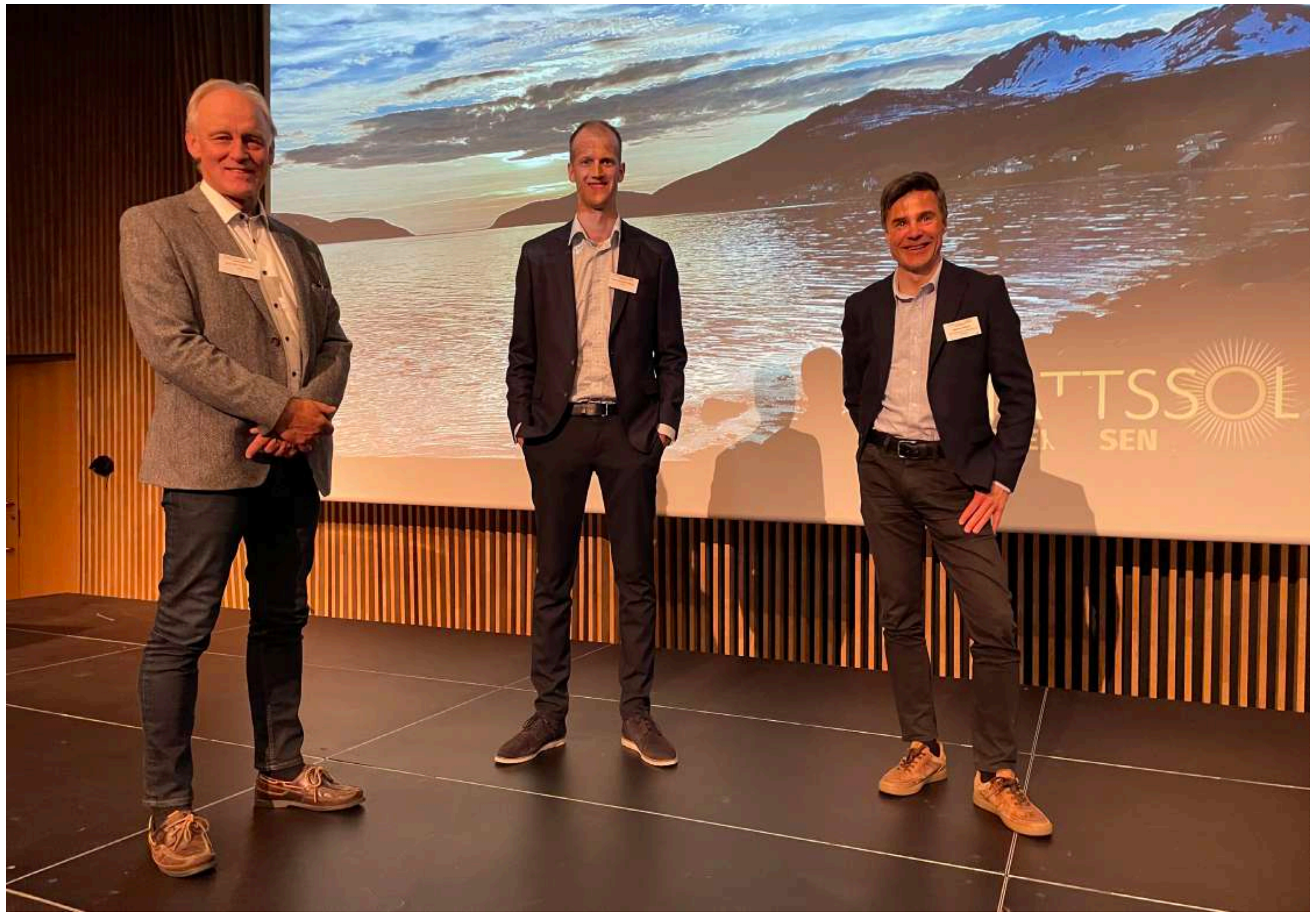
Towards that end, we will consider several approaches to evaluate the quality of predictors and their explanations and analyze their strengths and weaknesses with the aim to bridge those findings to applications and data provided by the consortium partners.

We further intend to obtain an overview over how explainability can be used to gain insight into or improve models including and beyond bias detection and bias removal. This point is relevant for instance to follow up work done in 2021 on semi-supervised acoustic target detection for innovation area marine sciences. Parts of this work is planned to build upon recent preliminary results on so-called information bottleneck strategies.

With respect to uncertainty quantification, we will focus on investigating recent advances in uncertainty estimation of attributed importance for example for representation learning such that we can evaluate and compare different methods. We intend to consider images used in high-stakes medical applications of relevance to our user partners. Qualitative feedback from experts regarding the performance of different methods could be asked to strengthen the comparative analysis.



Researchers and staff in Forskningsparken, Tromsø. Photo: Knut Jenssen.



Rolv-Ole Lindsetmo, Karl Øyvind Mikalsen and Robert Jenssen at the Midnight sun conference, June 2021. Photo: Norwegian Centre for E-healt Research.

Associated projects related to Visual Intelligence

Several associated projects contribute to Visual Intelligence as a research centre and the activities within the centre. The most relevant projects are:

Next generation explainable medical computer vision (MedEx)

The main aim of MedEx is to develop interpretable data-efficient computer vision methods that are able to use unannotated data and are applicable across hospitals and not limited to a particular imaging protocol RCN FRINATEK grant no. 315029.

Interpretable deep learning from electronic health records under learning constraints (DEEPehr)

The main aim of DEEPehr is to develop novel unsupervised and weakly supervised deep learning methodology to exploit the wealth of unannotated patient data for better quality of care.
RCN IKTPLUSS grant no 303514.

Ubiquitous cognitive computer vision for marine services (Cogmar)

The main aim of Cogmar is to enable deep learning technology for computer vision problems for non-standard images to solve key big data computer vision challenges in the marine sector.
RCN IKTPLUSS grant no. 270966.

Visual Intelligence collaborates closely with the Centre for research-based innovation in marine acoustic abundance estimation and backscatter classification – SFI Crimac. Crimac leverages new wideband echo sounders to create new opportunities to monitor fish and marine organisms for marine Norwegian science and industry.

Close ties exist also to SFI Biginsight, hosted by the Norwegian Computing Center, and to the SFI Cirfa, hosted by UiT The Arctic University of Norway. Visual Intelligence activities furthermore partially works in synergy with the Norwegian Nuclear Medicine Consortium.

New spin-off projects started in 2021

Consortium for Patient-Centered Artificial Intelligence (CPCAI)

CPCAI is an interdisciplinary project funded over UiT's strategic fund. The aim of CPCAI is to research new solutions for diagnosis support and decision support and to enable clinical implementation of AI solution.

Industry PHD projects

Two new industry PhD-projects were started in 2021 both at UiT with partners outside of the VI consortium. One concerns data-driven care pathways and the other one concerns computer vision related to UAVs.

Inigo Zubiavrre Martinez , Samuel Kuttner, Gerd Berge and Rune Sundset at PhD defense, May 28th 2021, Photo: Inga Bruun.

Benjamin Ricaud, Sébastien Lefèvre, Qinghui Liu and Alfred Hanssen at PhD defense December 8th 2021. Photo: Robert Jenssen.

PhD Defenses on associated projects

Samuel Kuttner

Advancing quantitative PET imaging with machine learning

Summary: Positron emission tomography (PET) is a medical imaging technique that allows visualization and measurement of biological processes in the body. It is an important tool in the detection, staging, and treatment response assessment of many diseases, including cancer, neurological and cardiovascular conditions, inflammation and infection. PET images may also be used as input-data into machine-learning-based prediction models for disease state and survival.

There are many factors which, unless accounted for, may hamper PET-based measurements. This thesis investigates how imaging artifacts and subject motion affect PET-based tumor measurements and machine learning-based prediction models. Furthermore, a simplified and non-invasive machine-learning-based approach is proposed, for estimating the invasive arterial blood measurements required for the analysis of time-varying PET-data. This may simplify PET measurements in future clinical and research studies.

Trial lecture:

"Deep learning-guided image reconstruction in PET and CT imaging"

Supervisors:

- Associate Professor Rune Sundset, Department of Clinical Medicine, Faculty of Health Sciences, UiT The Arctic University of Norway
- PhD Jan Axelsson, Faculty of Medicine, University of Umeå
- Professor Robert Jenssen, Department of Physics and Technology, UiT The Arctic University of Noway.

Evaluation Committee:

- Professor Habib Zaidi, University of Geneva. – 1. Opponent
- PhD Flemming Littrup Andersen, University of Copenhagen. - 2. Opponent
- Associate Professor Gerd Berge, Department of Medical Biology, Faculty of Health Sciences, UiT The Arctic University of Noway. (internal member and leader of the evaluation committee)

Qinghui Liu

Advancing land cover mapping in remote sensing with deep learning

Summary: Automatic mapping of land cover in remote sensing data plays an increasingly significant role in several earth observation (EO) applications, such as sustainable development, autonomous agriculture, and urban planning. Due to the complexity of the real ground surface and environment, accurate classification of land cover types is facing many challenges. This thesis provides novel deep learning-based solutions to land cover mapping challenges such as how to deal with intricate objects and imbalanced classes in multi-spectral and high-spatial resolution remote sensing data.

Trial lecture:

«Explainability in deep learning, from convolutional neural networks to graph neural networks»

Supervisors:

- Professor Robert Jenssen, Department of Physics and Technology, UiT (main supervisor)
- Senior Scientist Arnt-Børre Salberg, Norwegian Computing Center
- Associate Professor Michael Kampffmeyer, Department of Physics and Technology, UiT

Evaluation Committee:

- Professor Sébastien Lefévre, University of South Brittany, Frankrike (1. Opponent)
- Professor Anne Solberg, UiO (2. opponent)
- Associate Professor Benjamin Ricaud, Department of Physics and Technology, UiT (internal member and leader of the evaluation committee)

NLDL 2021

The Northern Lights Deep Learning Conference – NLDL – is an international scientific conference covering the latest topics in deep learning research. The conference is organized by Visual Intelligence and the UiT Machine Learning Group. NLDL 2021 was the 4th edition of the conference, organized January 14-15, with a mini deep learning school (tutorials) at January 13. There were 200 registered participants at the conference, from 20 different countries.

The conference had to be organized digitally due to the corona pandemic. NLDL has previously featured the biggest names in deep learning as keynote speakers. Examples include Gitta Kutyniok, Marlen de Bruijne, Julia Schnabel, XiaoXiang Zhu, Bernhard Schölkopf, Christoph Lampert, Dino Sejdinovic, Wojciech Samek.

For NLDL 2021, this trend continued, and the keynote speakers were:

Prof. Dr. Laura Leal-Taixé

Technical University of Munich

Prof. Dr. Laura Leal-Taixé is a tenure-track professor (W2) at the Technical University of Munich, leading the Dynamic Vision and Learning group. Before that, she spent two years as a postdoctoral researcher at ETH Zurich, Switzerland, and a year as a senior postdoctoral researcher in the Computer Vision Group at the Technical University in Munich. She obtained her PhD from the Leibniz University of Hannover in Germany, spending a year as a visiting scholar at the University of Michigan, Ann Arbor, USA. She pursued B.Sc. and M.Sc. in Telecommunications Engineering at the Technical University of Catalonia (UPC) in her native city of Barcelona. She went to Boston, USA to do her Masters Thesis at Northeastern University with a fellowship from the Vodafone foundation. She is a recipient of the Sofja Kovalevskaja Award of 1.65 million euros for her project socialMaps.

Elsa D. Angelini

Institute of Translational Medicine and Therapeutics (ITMAT) within NIHR Imperial Biomedical Research Centre (BRC)

Elsa D. Angelini is the co-lead of the Data Science Group in Institute of Translational Medicine and Therapeutics (ITMAT) within NIHR Imperial Biomedical Research Centre (BRC). She is also the co-director of the Heffner Biomedical Imaging Laboratory at Columbia University and is affiliated with the Department of Data-Signal-Image at Telecom Paris (Associate Professor / on leave). She has co-authored over 140 peer-reviewed articles and has graduated 19 PhD students. She is a Senior Member of IEEE and was the Vice-President for Technical Activities for IEEE EMBS (2017-19).

Lars Kai Hansen

Technical University of Denmark

Lars Kai Hansen has MSc and PhD degrees in physics from University of Copenhagen. Since 1990 he has been with the Technical University of Denmark, where he currently heads the Section for Cognitive Systems. He has published more than 300 contributions on machine learning, signal processing, and applications in AI and cognitive systems. His research has been generously funded by the Danish Research Councils and private foundations, the European Union, and the US National Institutes of Health. He has made seminal contributions to machine learning including the introduction of ensemble methods('90) and to functional neuroimaging including the first brain state decoding work based on PET('94) and fMRI('97). In the context of neuroimaging he has developed a suite of methods for visualizing machine learning models and quantification of uncertainty. In 2011 he was elected "Catedra de Excelencia" at UC3M Madrid, Spain.

Arthur Gretton

Centre for Computational Statistics and Machine Learning (CSML) at UCL

Arthur Gretton is a Professor with the Gatsby Computational Neuroscience Unit, and director of the Centre for Computational Statistics and Machine Learning (CSML) at UCL. He received degrees in Physics and Systems Engineering from the Australian National University, and a PhD with Microsoft Research and the Signal Processing and Communications Laboratory at the University of Cambridge. He previously worked at the MPI for Biological Cybernetics, and at the Machine Learning Department, Carnegie Mellon University. Arthur's recent research interests in machine learning include the design and training of generative models, both implicit (e.g. GANs) and explicit (high/infinite dimensional exponential family models and energy-based models), nonparametric hypothesis testing, survival analysis, causality, and kernel methods.

Roland Vollgraf

Technical University of Berlin

Roland Vollgraf is the Head of Zalando Research and obtained his Ph.D. at the Technical University of Berlin in Machine Learning and Statistical Signal Processing. Roland was integral to the establishment of Zalando Research and has been with Zalando since 2013. He previously worked as Head of Research for GA Financial Solutions GmbH and conducted the development of asset risk models and quantitative trading strategies. Current research interests include Deep Learning and Large Scale Bayesian Inference.

WWW.NLDL.ORG

Changkyu Choi, Photo: Knut Jenssen.

NLDL 2021 featured several very good tutorials especially aimed for graduate students and newcomers to the field, including talks by Arnt-Børre Salberg, Norwegian Computing Center, Håkon Hukkelås, NTNU, Fabian Brickwedde, Bosch & Goethe University Frankfurt, as well as Lilja Øvrelid and Jeremy Barnes, both UiO.

The program consisted of a mix of innovation and industry-oriented presentations as well as presentations about recent methodological developments within deep learning. Full paper submissions were published in the NLDL proceedings.

Keynote talks, tutorials, and presentations can be found at the Visual Intelligence YouTube channel.

The conference was rounded up by a highly interesting panel session including the keynote speakers and moderated by Klas Pettersen, CEO of NORA (Norwegian Artificial Intelligence Research Consortium).

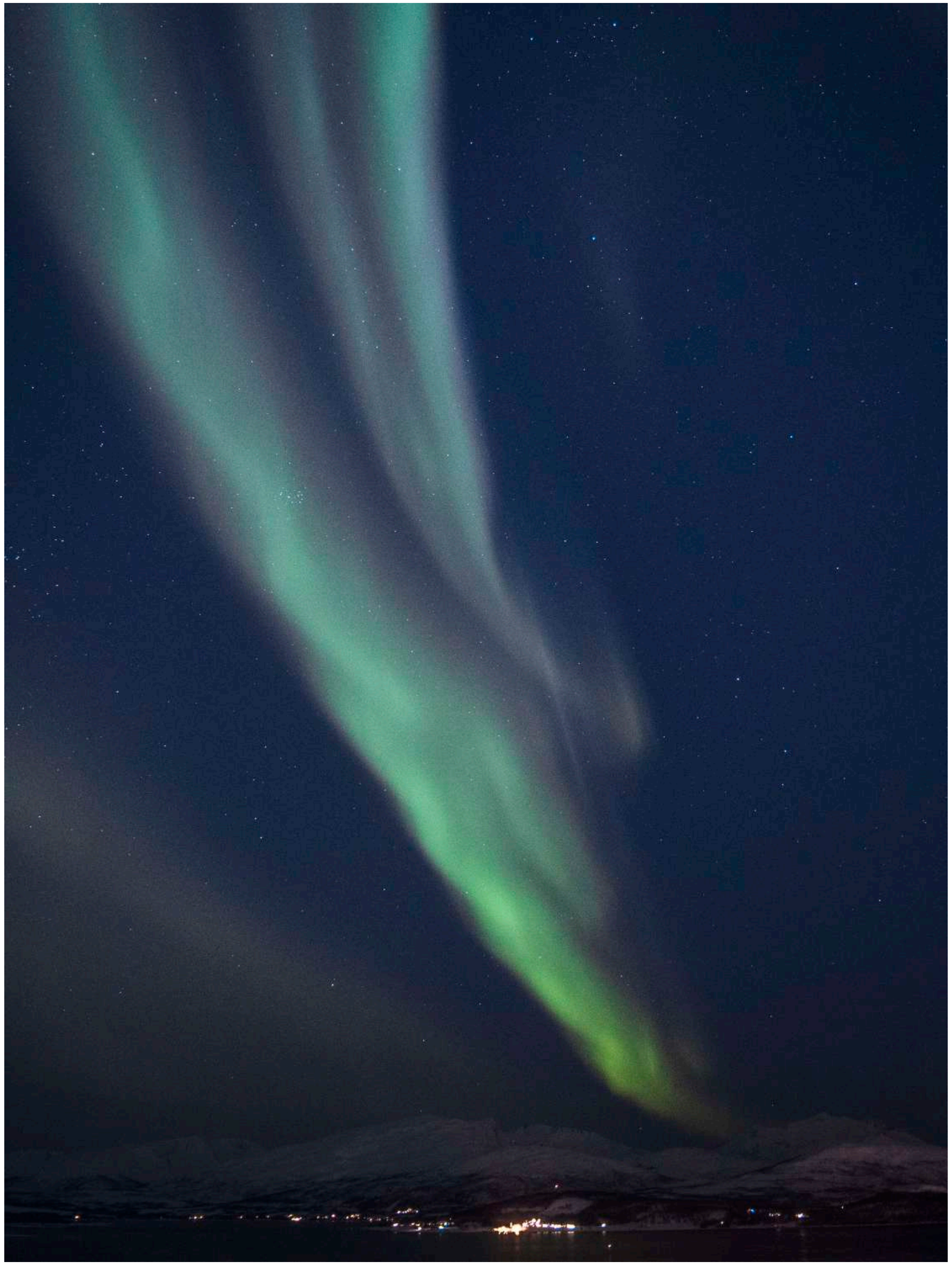
NLDL gathers the Norwegian community as well as a large international participation and we thank session chairs from Norwegian institutions including Narada Dilp Warakagoda, Norwegian Defense Research Establishment, Rudolf Mester, NTNU, Aase Reyes, OsloMet, Daniel Romero, UiA, and Ana Ozaki, UiB.

The NLDL web site:
http://nldl.org

The NLDL proceedings web site:
https://septentrio.uit.no/index.php/nldl

The Proceedings of NLDL are approved as a level 1 publication in the Norwegian national list of authorized research publication channels.

NLDL 2021, similar to all previous editions, received support for organization of events from the Research Council of Norway, in 2021 from grant no 322969.



Northern lights. Photo: Luigi Luppino.

Lunch break at Visual Intelligence days, Srishti Gautam, Changkyu Choi, Luigi Luppinoand and Ane Blazquez Garcia. Photo: Inger Solheim.

Visual Intelligence Days

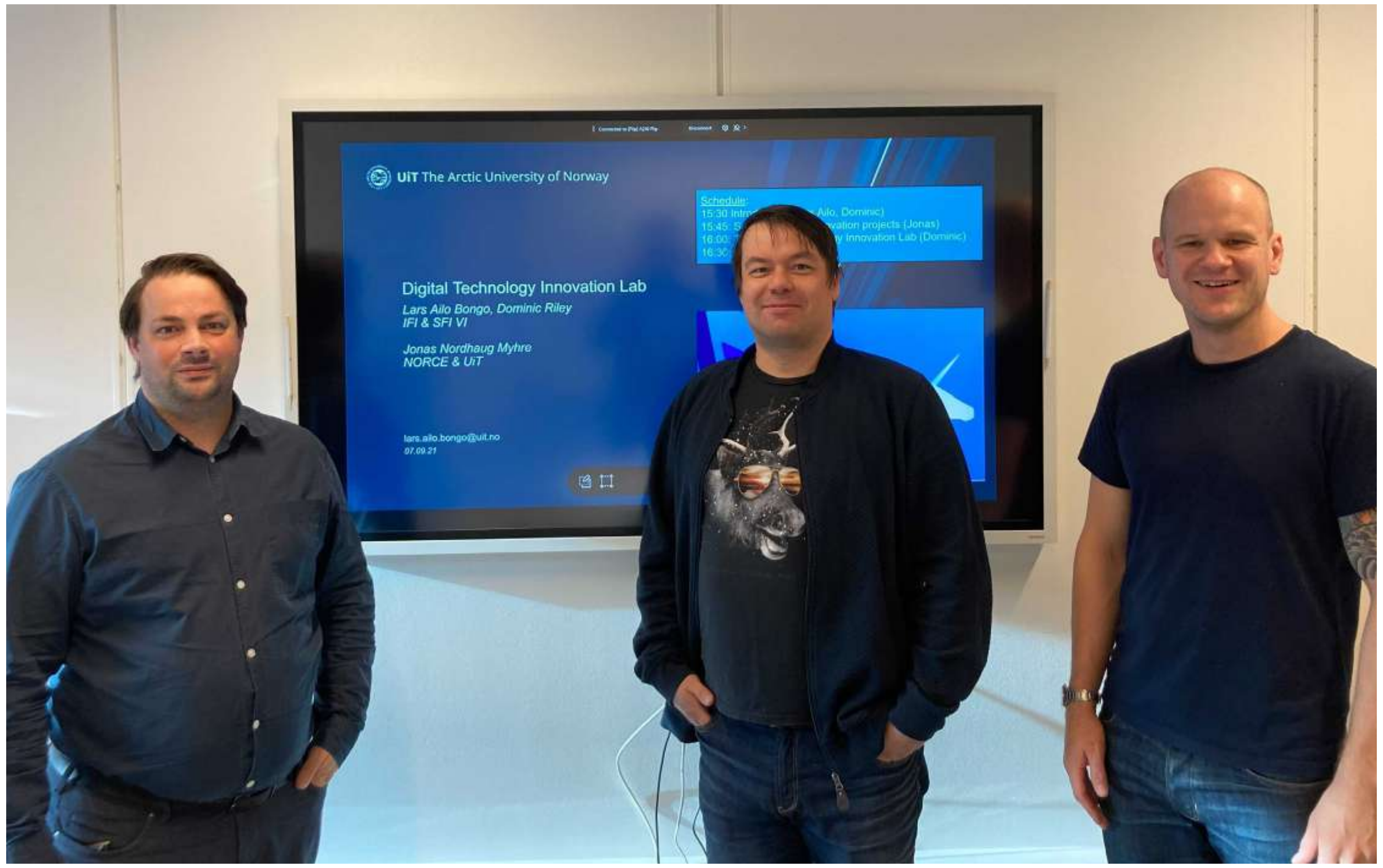
The very first Visual Intelligence Days took place 18-20th October in Oslo. This was our first chance to meet physically and a total of 70 attendants seemed very happy at the chance to finally meet outside Teams and Zoom. Research partners, including students, and user partners were well represented. In addition, two representatives from our Scientific and Innovation Advisory Committee were able to join the event. The main aim of the VI-Days was to get to know each other better across institutions and fields of work, through dialogue, interaction, discussions, networking and socializing to build a good basis for collaboration.

The first day the focus was on the students and young researchers and the establishment of the Visual Intelligence Graduate School (VIGS). Twenty young researchers and students met to get to know each other and to discuss their wishes and visions for the VIGS. Afterwards the discussions continued over tapas and wine where new collaborations and friendships were formed.

The second day gathered all participants and started out with welcoming words from the director, followed by short selected presentations on research activities from the innovation areas and research challenges of Visual Intelligence. The presentations covered research within all innovations areas applied to a range of data sources ranging from echosounder data, cardiac ultrasound and seismic to aerial photographs. The second half of the day was set aside for discussions across innovation areas, with table discussions around the four research challenges. The aim was to identify interests and challenges across user partners and map synergies. The more formal part of the day was finished up with a poster and mingling session with even more room for discussions which also continued into dinner.

The user partners and their challenges were the focus of the last day which started out with short presentations from each partner on their data, problems and work. This formed a good background for the next sessions with discussions formed around each innovation area with an aim of identifying challenges and possible research directions. Everything was summed up at the end of the day ending a few very fruitful days with good discussions and interaction.

Top: Audience at Visual Intelligence days. Photo: Inger Solheim. Bottom: Srishti Gautam presenting at Visual Intelligence days. Photo: Robert Jenssen.



Dominic Riley, Lars Ailo Bongo and Jonas Myhre at innovation workshop September 2021. Photo: Erland Grimstad.

Working with innovations

The centre's overall strategy for defining, mapping and following up innovations with user partners is that research activities in the centre are generally based on close collaboration and co-publishing, and that pilot software and data flow are set up as much as possible such that the user partner can further develop the new solutions within their own organization.

Digital Technology Innovation Lab

Visual Intelligence has been instrumental in the establishment of the «Digital Technology Innovation Lab» at UiT. This Lab is designed to target student innovation and startup activities. The initiative includes the employment of a «business mentor» position for one year financed by Troms and Finnmark county, assigned to the Visual Intelligence in collaboration with the UiT Department of Informatics. In 2021, this innovation lab has worked on 3 specific start-up projects and has arranged several innovation workshops.
Read more at: https://uit-dtil.github.io

NORA.startup

One of Visual Intelligence's innovation coordinators, Prof. Lars Ailo Bongo (UiT) is in the steering group for NORA.startup. Through NORA.startup, the centre's researchers have been able to follow webinars and workshops that deal with processes around innovation and startups.
Read more at: http://nora.ai/nora-startup

Facilitating development and implementation of AI in clinical use

Visual Intelligence has been central in the establishment of the UNN-UiT "Senter for pasientnær kunstig intelligens" - SPKI. This unit is created with partial funding from Helse Nord with the aim to facilitate the actual implementation of AI and Visual Intelligence solutions in medicine and health. Karl-Øyvind Mikalsen (UNN/UiT) is the daily manager. Rolv-Ole Lindsetmo (UNN/UiT) is "Clinical Advisor" and Visual Intelligence's Director Robert Jenssen is «Technical Advisor» in SPKI. We arrange regular meetings every second Tuesday for researchers, clinicians and other people with an interest in AI and healthcare. The goal of these meetings is to inform about, present and discuss ongoing activity on AI and health, and to be a meeting point where you can establish new collaborations and share ideas on clinical AI. Read more at: http://spki.no.

Karl Øyvind Mikalsen at opening of Senter for pasientnær kunstig intelligens (SPKI) June 2021. Photo: Norwegian Centre for E-health Research.

Andrea Marioni, in Cambridge. Photo: Private.

Internationalization activities Visual Intelligence

Visual Intelligence signed in 2021 as the first research centre in Norway a formal collaboration agreement with the Alan Turing Institute in the UK. This collaboration agreement will give unprecedented opportunities for:

- A long-term structured research collaboration program
- Student exchange and joint supervision
- Jointly funded projects and activities

Instrumental to the Visual Intelligence-Turing Partnership is Chief Scientist Professor Mark Girolami, University of Cambridge/The Alan Turing Institute and UiT The arctic university of Norway.

The exchange of personnel has already started. Visual Intelligence Assoc. Prof. Andrea Marinoni has visited Girolami's group at Cambridge and Turing for the fall semester 2021.

Adjunct professors

Professor Gitta Kutyniok

Ludwig Maximilian University of Munich and UiT The Arctic University of Norway

Gitta Kutyniok is an adjunct professor in Visual Intelligence via the Machine Learning Group at UiT. She is an applied mathematician known for her research in deep learning and image processing, as well as harmonic analysis and compressed sensing. She is the Bavarian AI Chair for "Mathematical Foundations of Artificial Intelligence" in the institute of mathematics at the Ludwig Maximilian University of Munich. In the period 2011-2020, she was the Einstein Chair in mathematics at the Technical University of Berlin, where she also held courtesy affiliations with computer science and electrical engineering. Prior to that, Kutyniok has worked at Paderborn University, the Georgia Institute of Technology, the University of Giessen, Washington University in St. Louis, Princeton University, Stanford University, and Yale University.

Professor Mark Girolami

University of Cambridge and UiT The Arctic University of Norway

Mark Girolami is an adjunct professor in Visual Intelligence via the Machine Learning Group at UiT. He is known for his contributions to the machine learning research field, and he also has ten years of experience as a Chartered Engineer within IBM. In March 2019 he was elected to the Sir Kirby Laing Professorship of Civil Engineering within the Department of Engineering at the University of Cambridge where he also holds the Royal Academy of Engineering Research Chair in Data Centric Engineering. Prior to joining the University of Cambridge, Girolami held the Chair of Statistics at Imperial College London, having had prior positions at Warwick University and at Glasgow University. He was one of the original founding Executive Directors of the Alan Turing Institute the UK's national institute for Data Science and Artificial Intelligence, after which he was appointed as Strategic Programme Director at Turing, where he established and continues to lead the Lloyd's Register Foundation Programme on Data Centric Engineering.

Ane Blazquez Garcia. Photo: private.

Guest researcher:

Visual Intelligence benefits from a broad range of additional international collaborative research projects. The centre hosted for instance Ane Blazquez Garcia from the University of the Basque Country in the fall of 2021.

Greeting from Ane Blazquez Garcia:

My name is Ane Blazquez Garcia, and I am currently finishing my Ph.D. studies at Ikerlan in collaboration with the University of the Basque Country (UPV/EHU) in Spain.

For my third PhD thesis paper, I was investigating anomaly detection, and it was then that I found that Visual Intelligence via the UiT Machine Learning Group part of the centre has experience in this topic. Therefore, I started to explore the group more deeply and noticed that they also had expertise in medical data, which is also of interest to me. The purpose of the research in Visual Intelligence is mainly orientated to images, however relevant to topics of my interest such as anomaly detection and quantification of uncertainty, in a time series analysis context, and not only images. Mainly for all these reasons, I decided that Tromsø would be a good destination for a research stay. Thus, I completed a three-month research stay there.

The research stay in Tromsø has been very enriching in many aspects and has helped me grow both professionally and personally. Professionally, the stay has been a constant learning experience where the discussions and meetings in the team have always been very rewarding and have helped me improve my work. The working environment of the group is very positive, and the team dynamic is very enriching. On a personal level, I have met wonderful people that have given me moments full of joy and fun. Also, I have had the opportunity to make amazing plans and enjoy the beauty of Tromsø's nature. It was definitely a good choice to join the Visual Intelligence centre and the UiT Machine Learning Group in Tromsø is very enriching.

On a personal level, I have met wonderful people that have given me moments full of joy and fun. Also, I have had the opportunity to make amazing plans and enjoy the beauty of Tromsø's nature. It was definitely a good choice to join the UiT Machine Learning Group in Tromsø.

Robert Jenssen at opening of Norwegian Research Center for AI Innovation (NTNU) Photo: Kai T. Dragland (NTNU).

Outreach

Keynote talks and invited talks where Visual Intelligence was presented (selection)

- Swedish Deep Learning and Image Analysis Symposium
- Bristol Interactive AI Summer School
- Nordic Conference on Patient Oriented Products
- NORA explains AI – podcast
- Norwegian Medical Student's Association
- Norwegian Hospital Pharmacists' Association
- Midnight Sun Conference for Patient-Centered AI
- NORA/NAIL Webinar
- DIPS Developer Days
- Norway Towards 2030 UiT
- The Norwegian Academy of Science and Letters
- County Governor of Troms and Finnmark
- Federation of International Nordic Medical Students' Organisations
- Women's Health Committee
- NorwAI Innovate Conference

Screenshot: Changkyu Choi.

Visual Intelligence online seminars 2021

Kristoffer Knutsen Wickstrøm, PhD candidate, Faculty of Science and Technology, UiT –The Arctic University of Norway, Tromsø, Norway
Recent advances in explainable deep learning and how to model uncertainty in explainability

Olav Brautaset, Norwegian Computing Centre
Marine Acoustic Classification: Supervised Semantic Segmentation of Echosounder Data using CNNs

Andrew Gilbert, GE Healthcare
Generating Synthetic Labeled Data from Existing Anatomical Models: An Example with Echocardiography Segmentation

Torgeir Brenn, KSAT
Using Neural Networks for Satellite Based Maritime Monitoring

Andreas Kleppe, Institute for Cancer Genetics and Informatics, Oslo University Hospital, and Department of Informatics, University of Oslo
Designing deep learning studies in medical diagnostics and beyond

Gitta Kutyniok
Deep Learning meets Modeling: Taking the Best out of Both Worlds

Øivind Due Trier, Norsk Regnesentral
Automated building detection from airborne hyperspectral and lidar data

Jens Grimsgaard, Senior Geophysicist, Equinor
Applying Deep Learning for Seismic Interpretation

Changkyu Choi , UiT –The Arctic University of Norway
Marine Vision: When Visual Intelligence Meets Marine Science

Atsuto Maki, KTH Royal Institute of Technology, Sweden
On Regularization and Reliability of Deep Convolutional Networks

Raul Santos Rodriguez, Turing AI Fellow, University of Bristol
Machine learning with imperfect labels

Didrik Nielsen, Technical University of Denmark - DTU
Normalizing Flows and Diffusion Models for Images and Text

Sandy Engelhard, Assistant Professor at Heidelberg University Hospital
Unsupervised Deep Domain Adaptation in Cardiac Imaging

Scott Hoskings, Turing Fellow, British Antarctic Survey
Extracting understanding from scientific imagery at The Alan Turing Institute

Ehsan Naeini, PhD, Chief Product Officer, Earth Science Analytics AS
Capturing Uncertainty in Machine Learning for Geoscience Applications

Ehsan Naeini, Earth Science Analytics AS
Capturing Uncertainty in Machine Learning for Geoscience Applications

Workshops

Alexander Binder, University of Oslo,
Explainability beyond eyeballing heatmaps: towards improving models

Mara Graziani, University of Applied Sciences of Western Switzerland,
Sharp-LIME: Sharpening Local Interpretable Model Agnostic Explanations for Digital Pathology

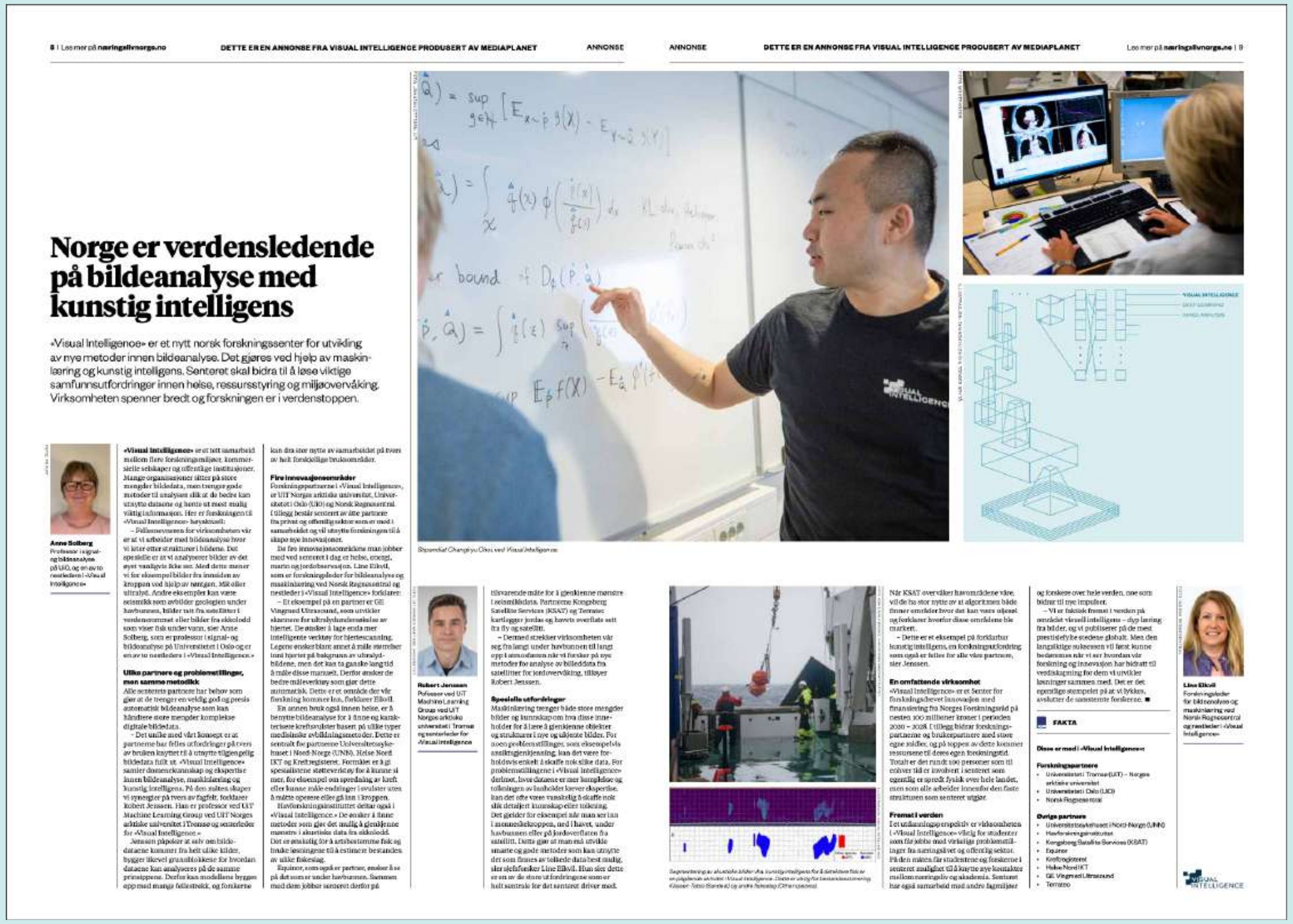
Shujian Yu, UiT –The Arctic University of Norway, Information
Bottleneck for the Understanding of Deep Neural Networks in the Training and the Decision-Making Processes

Kristoffer Wickstrøm, UiT –The Arctic University of Norway,
RELAX: Representation Learning Explainability Explainable AI

Lars Ailo Bongo, UiT –The Arctic University of Norway
Using sensitive data in Visual Intelligence

Hao Song, University of Bristol, UK,
Probability Calibration for Predictive Machine Learning

Geir Storvik, University of Oslo,
Bayesian methods within machine learning



Norge er verdensledende på bildeanalyse med kunstig intelligens

«Visual Intelligence» er et nytt norsk forskningssenter for utvikling av nye metoder innen bildeanalyse. Det gjøres ved hjelp av maskinlæring og kunstig intelligens. Senteret skal bidra til å løse viktige samfunnsutfordringer innen helse, ressursstyring og miljøovervåking. Virksomheten spenner bredt og forskningen er i verdenstoppen.

Reprint: Mediaplanet.

Jonathan Edward Berezowski , UiT –The Arctic University of Norway,
Learning Network Architectures with Bayesian Neural Networks
Confidence & Uncertainty

Benjamin Kellenberger, EPFL,
When a Few Clicks Make All the Difference

Alba Ordonez, Norwegian Computing Centre – NR,
Deep Domain Adaptation Applied to Automatic Fish Age Prediction
Learning from limited data

In the media 2021

Nils Olav Handegard; Changkyu Choi
Arbeidet hans sparer forskerne for store ressurser, og åpner for et selvstyrt fiskeri. https://www.fiskeribladet.no/ [Avis] 2021-08-26

Robert Jenssen
Har "kapret" internasjonal avtale. uit.no [Internett] 2021-07-02

Robert Jenssen
Robert skal lede nytt UiT-senter verdt 300 millioner kroner.
iTromso [Avis] 2021-01-17

Robert Jenssen
UiT skal samarbeide med verdensledende institutt på forskning innen kunstig intelligens. Folkebladet [Avis] 2021-07-07

Robert Jenssen
UiT skal samarbeide med verdensledende institutt på forskning innen kunstig intelligens. iTromsø [Avis] 2021-07-07

Robert Jenssen
Visual Intelligence åpnet og klare til å løse viktige samfunns-utfordringer.
uit.no [Internett] 2021-01-14

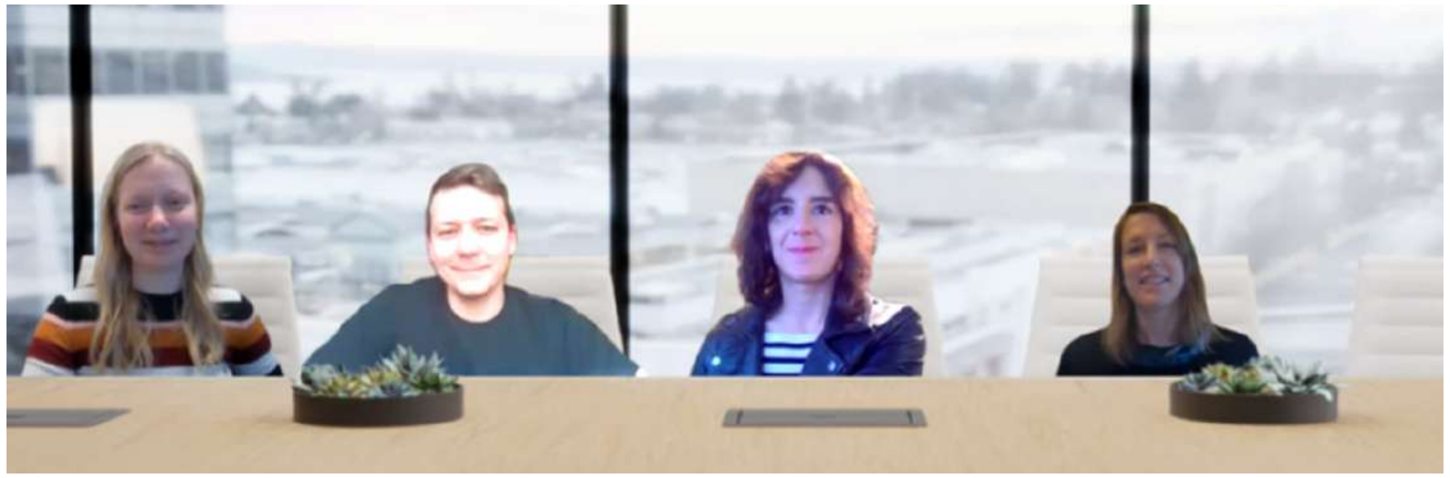
Robert Jenssen; Anne H Schistad Solberg; Line Eikvil
Norge er verdensledende på bildeanalyse med kunstig intelligens.
[Avis] 2021-06-21

Michael Kampffmeyer
Fikk 12 millioner til bildetolking. uit.no [Internett] 2021-01-06

Michael Kampffmeyer
UiT-gruppe får millionstøtte for å tolke bilder.
iTromsø [Avis] 2021-01-11

Follow us:

Visual-intelligence.no | @SFI Visual Intelligence | @SFI_VI | @SFIvisualintelligence | @SFI-Visual-Intelligence



Top: VIGS management: Ingrid Utseth (NR), Kristoffer Wickstrøm (UiT), Alba Ordonez (NR) and Sarina Thomas (UiO). Screenshot: Alba Ordonez.
Bottom: Master students at UiT: Erland Grimstad, Harald L. Joakimsen and Joel Burman. Photo: Robert Jenssen.

PhD students at UiT: Changkyu Choi, Stine Hansen, Sara Björk, Harald Lykke Joakimsen, Rwiddhi Chakraborty, Magnus Størdal, Eirik Østmo and Srishti Gautam.
Photo: Knut Jenssen.

Researcher training & education

Visual Intelligence graduate school

The Visual Intelligence Graduate School (VIGS) is headed by and consists of early career researchers in the field of artificial intelligence (AI).

"VIGS fills an important gap in the education of researchers within this field, as it allows for rapid development and deployment of tutoring in a research field that evolves at a highly accelerated pace. VIGS is focused on hosting events, courses, and workshops on very recent developments, research, gender perspectives and diversity, as well as practical skills for early career AI researchers . We work towards facilitating collaboration across institutions, for example in the form of joint courses, and aim at being a natural meeting point for early career researchers both within Visual Intelligence and in the Norwegian AI community as a whole."

Kristoffer Wickstrøm represents VIGS in the NORA (Norwegian Artificial Intelligence Research Consortium) research school (NORA.research_school).

Master degrees 2021

Anton Garri Fagerbakk, UiT
Keeping Up with the Market: Extracting competencies from Norwegian job listings

Jonathan Berezowski, UiT
Trans-dimensional inference over Bayesian neural networks

Magnus Oterhals Størdal, UiT
Towards Unsupervised Domain Adaptation for Diabetic Retinopathy Detection in the Tromsø Eye Study

Joakim Warholm, UiT
Detecting Unhealthy Comments in Norwegian using BERT

Mona Heggen, UiO
An investigation of different interpretability methods used to evaluate a prediction from a CNN model.

Edward Fabian Bull, UiO
Introducing an Efficient Approach for Expressing Uncertainty in Deep Learning with Bayesian Neural Networks

New AI MSc study program at UiT connected to Visual Intelligence

UiT launched in 2021 a new MSc study program in AI. The program is closely aligned with Visual Intelligence. Many of the courses that Visual Intelligence researchers teach are mandatory in the program, and the intention is that industry connected to Visual Intelligence will help motivate cases to be incorporated into the course work and into student work and theses.

At the program's web page a promotion film can be viewed. The film is featuring Harald Lykke Benjaminsen. Harald is now a PhD student in Visual Intelligence. Associate Professor Michael Kampffmeyer, who is a Visual Intelligence PI, is the chair of this new study program.

Working to reduce the gender gap in AI

The development of AI solutions in Visual Intelligence innovation areas, will have impact on lives and society. Recognizing this is motivation to actively work to reduce the gender gap in AI and to create a diverse and inclusive work environment. In the AI tech-field women are generally underrepresented, and we believe we can reduce the gender gap by ensuing equal opportunities and high visibility of women within Visual Intelligence. When recruiting we are aware of the phrasing of our announcements, and how we marked the opportunities. Our goal is to have equal representation in all positions, outreach, events and governance.

To increase awareness, inspire and to educate on how to achieve gender balanced AI, we organize special events to promote women in AI. We have a high awareness of ethics, and on fostering a creative, inclusive and safe work environment where students and staff can shape the AI future.

Researchers associated with Visual Intelligence

Jørgen Andreas Agersborg
PhD student, UiT

Børge Solli Andreassen
PhD student, UiO

Stian Anfinsen
Associate Professor, UiT

Andreas Austeng
Professor, UiO

Sara Björk
PhD student, UiT

Changkyu Choi
PhD student, UiT

Line Eikvil
Chief research scientist, NR

Shristi Gautam
PhD student, UiT

Fred Godtliebsen
Professor, UiT

Stine Hansen
PhD student, UiT

Marit Dagny Kristine Jenssen
PhD student, UiT

Robert Jenssen
Professor, UiT

Thomas Haugland Johansen
PhD student, UiT

Michael Kampffmeyer
Associate Professor, UiT/NR

Samuel Kuttner
PhD student, UiT

Izzie Yi Liu
Senior Research Scientis, NR

Luigi Tommaso Luppino
Post doc., UiT

Sigurd Løkse
Researcher, UiT

Karl Øyvind Mikalsen
Associate Professor, UiT

Jonas Nordhaug Myhre
Researcher, UiT

Arnt-Børre Salberg
Senior Research Scientis, NR

Rajendra Sapkota
PhD student, UiT

Puneet Sharma
Associate Professor, UiT

Nikita Shvetsov
PhD student, UiT

Anne Solberg
Professor, UiO

Ingrid Utseth
Reseach Scientist, NR

Kristoffer Knutsen Wickstrøm
PhD student, UiT

Eirik Agnalt Østmo
PhD student, UiT

Andrea Marioni
Associate Professor, UiT

Benjamin Ricaud
Associate Professor, UiT

Lars Ailo Bongo
Professor, UiT

Olav Brautaset
Senior Research Scientist, NR

Camilla Brekke
Professor, UiT

James Claxton
PhD student, UiO

Edward Fabian Bull
PhD student, UiO

Marit Holden
Chief research scientist, NR

Kristine Baluka Hein
PhD student, UiO

Are Charles Jensen
Senior Research Scientis, NR/UiO

Sarina Thomas
Postdoctoral researchers, UiO

Durgesh Singh
PhD student, UiT

Gitta Astrid Hildegard Kutyniok
Adjunct Professor, UiT

Per Roald Leikanger
PhD student, UiT

Brian Liu
PhD student, UiT/NR

Jarle H. Reksten
Senior Reseacher, NR

Ahcene Boubekki
Postdoctoral researchers, UiT

Suaiba Amina Salahuddin
PhD student, UiT

Rwiddhi Chakraborty
PhD student, UiT

Mark Girolami
Adjunct Professor, UiT

Fredrik A. Dahl
Senior Reseacher, NR

Øystein Rudjord
Senior Reseacher, NR

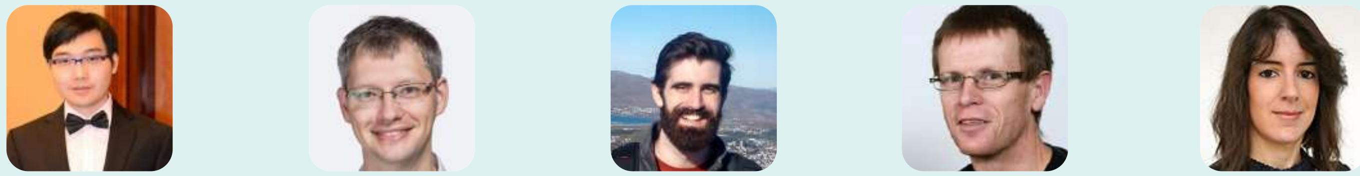
Rune Solberg
Head of Section for Earth Observation, NR

Øivind Due Trier
Senior Research Scientist, NR

Daniel Johansen Trosten
PhD student, UiT

Anders U. Waldeland
Reseacher, NR

Amund H. Vedal
Reseacher, NR



Shujian Yu
Associate Professor, UiT

Alexander Binder
Associate Professor, UiO

Theodor Anton Ross
PhD student, UiT

Geir Storvik
Professor, UiO

Alba Ordonez
Reseacher, NR

Jørgen A. Lund
PhD student, UiT

Tollef Jahren
PhD student, UiO

Ghadi Al Hajj
PhD student, UiO

Consortium partners

At Visual Intelligence we enable our consortium partners to utilize the full potential of their complex visual data and contribute to development of new and improved products and services.

The Cancer Registry of Norway collects data and produce statistics of the cancer prevalence in Norway and has an extensive research activity. The Cancer Registry is responsible for cancer screening in Norway and has altogether 200 employees.

The Cancer Registry is currently investigating AI for mammographic screening, an important reason for the Cancer Registry's role as a partner in Visual Intelligence, since demand is expected to rise for population-based screenings for more cancer forms.

For this to be feasible, reliable automatic or semi-automatic deep learning solutions are needed. This will enable use of more data and systematic analyses to detect changes over time in cancer characteristics, to help in the fight against cancer.

Equinor is a broad energy company with 21,000 employees committed to developing oil, gas, wind and solar energy in more than 30 countries worldwide.

Equinor has a major goal of becoming more data-driven and maximizing the value of the vast amount of data available by means of AI. This is a major motivation for being a partner in Visual Intelligence.

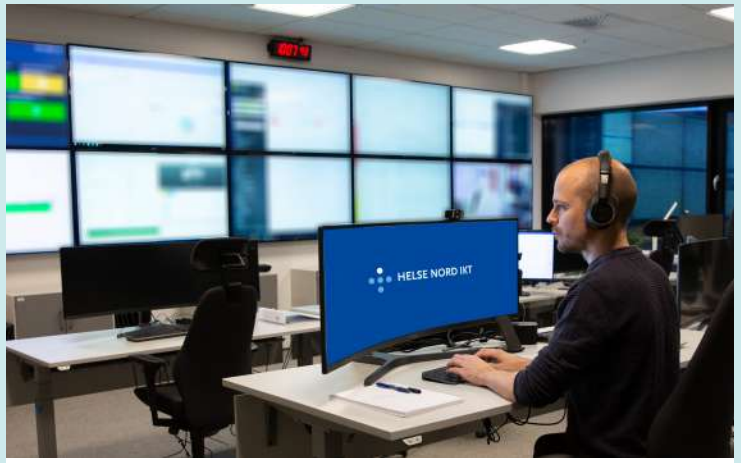
Parts of this aim include challenges related to analysis of the digital subsurface data, for instance use of seismic and borehole imagery, especially on the Norwegian Continental Shelf.

Extracting the most out of the subsurface data is important for future energy exploration. Automated analysis of different types of imagery and visual data by deep learning can lead to large savings in time and resources and more efficient and precise exploration. The amount and quality of labelled training data is a challenge in this field, as well as exploitation of prior knowledge of the geology, dependencies in space and time.

KSAT's mission is to be the world's leading commercial satellite centre operating a network of global ground stations, consisting of more than 200 remotely controlled antennas. With 23 sites worldwide, KSAT provides optimized locations for satellites in polar, inclined and equatorial orbits. Headquartered in Tromsø, Norway, and with 250 employees, including at sales offices in Oslo, Stockholm and Colorado, KSAT is Norway's main satellite data provider specializing in delivery of operational near real-time services to an international market.

A main interest of KSAT as a partner in Visual Intelligence is for innovating the existing maritime surveillance services for vessel detection and oil spill monitoring. The center will enable KSAT to develop more efficient deep learning analytics and fast delivery of such products to improve service quality and decrease production time.

Exploring context and dependencies in satellite imagery over a combination of radar and optical satellites is of prime importance, as well as researching new AI solutions to quantify uncertainties in the detections. Advances in utilizing weak and/or noisy labels will further increase the value of KSAT vast archive of historical data, which is a world leading but noncurated collection of analyses performed under strict time constraints and to non-identical customer requirements.



Helse Nord IKT is the technology provider for the Northern Norway Regional Health Authority (Helse Nord). With 300 employees, 18000 users, and 24/7 services, Helse Nord IKT provides IT services and technological solutions over a large geography in Nordland, Troms and Finnmark.

Helse Nord IKT is a partner in Visual Intelligence with an aim to reap the benefits of AI in health through data-as-a-service and solutions for security and integration in AI deployments, particularly by facilitating necessary infrastructure and data retrieval on-demand for the University Hospital of North Norway and other hospitals.

This will enable efficient and compliant use of data for research and deep learning/AI for complex visual data and beyond. Helse Nord IKT has special competence within IT services for storage, analytics, and integration with cloud services and national platforms. Helse Nord IKT thus enable and prepare for AI solutions within health for scaled-up use in deployment and production.

GE Healthcare

GE Vingmed Ultrasound's vision is to be a leading provider of AI solutions that increases efficiency and improve diagnostic confidence, leading to improved outcomes for patients. With offices in Horten, Oslo and Trondheim, Norway, GE Vingmed Ultrasound has 220 employees, 50% of these in R&D, and annual revenues in the order of 200 mill USD.

As a partner in Visual Intelligence, GE Vingmed Ultrasound is particularly focused on deep learning for developing innovative products through increasingly more intelligent cardiac ultrasound scanners capable of assisting the user to increased productivity and accelerated decision making. This can give both improved diagnostic accuracy, and improved productivity by automating repetitive tasks.

To achieve the next generation intelligent ultrasound scanners, new solutions are needed for learning robustly from limited data, handling human variation in the labelling process, dealing with rare cases and data shift, as well as handling uncertainty in data and obtaining interpretable predictions.

INSTITUTE OF MARINE RESEARCH

The Institute of Marine Research (IMR) is one of the biggest marine research institutes in Europe, with about 1,000 employees. IMR has a mission to be a leader in providing knowledge to ensure sustainable management of resources in our marine ecosystems.

IMR's monitoring and research activities are to a large extent data driven, and efficient data analysis and processing pipelines are important to achieve the mission. IMR collects vast amounts of complex marine observation data containing valuable information needed to ensure sustainable fisheries and monitor the ecosystems. Image data may come from sources such as acoustic surveys, trawl images, subsea videos and underwater microscope videos. Manual analysis of these is a bottleneck for the extraction of new knowledge.

IMR is a partner in Visual Intelligence with an aim to leverage deep learning to make headway for automated AI solutions, needed for the next generation marine big data services. The outputs from these solutions are intended as inputs to models for abundance estimation which again is a basis for setting of fishing quotas. Learning from image data which is limited with respect to available annotations as well as quality, and that are reliable and interpretable, are of key concern for the development of such innovations.

TERRATEC

Terratec operates a fleet of aircrafts with advanced sensor technology and is the leading aerial survey company in Scandinavia. With a head office in Oslo, altogether 240 employees, and an annual turnover of around 40 mill USD, Terratec do 3D remote sensing worldwide and with a focus on integrating advanced machine learning into the production process for increased efficiency and quality.

As a partner in Visual Intelligence, Terratec will have special focus on deep learning for automatic change detection in aerial images and automatic detection of interesting objects in vertical and oblique images from an airborne camera system for instance for forest-related applications.

This will enable innovations yielding less manual work, reduced production costs, more reliable solutions, and increased competitiveness for the company.

UNIVERSITETSSYKEHUSET NORD-NORGE
UNIVERSITY HOSPITAL OF NORTH NORWAY

UNN is the major hospital in North Norway. Having 6300 employees, and through 400000 yearly patient encounters, UNN provides diagnosis and treatment at an international high level for the population in Northern Norway.

UNN aims to explore deep learning technology for medical image analysis, with a major focus on cancer diagnosis and treatment. One example is for the detection of locally spread lymph node metastasis in rectal cancer and implications for therapeutic strategy. New AI tools for diagnostic accuracy and possible aid for radiologists and clinicians for colorectal cancer patients, as well as improved MRI diagnosis of prostate cancer and lung cancer.

Research partners

Visual Intelligence unites three of the most experienced and best research institutions in deep learning and machine learning for visual data in Norway. The research partners have a history of long-time collaboration, joint positions and joint projects, and have complementary strengths.

UiO : University of Oslo

UiO and their digital and signal image analysis (DSB) group is leading in image analysis. For UiO machine learning is an important part of the strategy of the Department of Informatics, and the Faculty for Natural Science. Visual Intelligence will also be a natural part of a new section for Machine Learning at Department of Informatics, and a new centre for Data Science and Computational Science at UiO.

NR Norsk Regnesentral
NORWEGIAN COMPUTING CENTER

NR is a private, independent, non-profit foundation established in 1952. NR carries out contract research and development projects in the areas of information and communication technology and applied statistical modeling. For NR projects involving visual data have for decades been important, and the volume has increased significantly over the last years, especially by the use of deep learning techniques. NR's ambitious aim is to be the European leader of applied deep learning research and innovation. Visual Intelligence is crucial to fulfil these ambitions.

UiT The Arctic University of Norway

UiT is the host organization of Visual Intelligence. Within machine learning, UiT is the leading national research environment, having long pushed the frontier of machine learning research within deep learning, computer vision and industry-related research. Visual Intelligence is for UiT a major component in the new interdepartmental study program in AI and supports several strategic interfaculty research and innovation projects funded by UiT, Horizon Europe and the Research Council of Norway. Visual Intelligence consists of researchers from several research groups at the Faculty of Science and Technology.

Publications 2021

Journal and published conference papers

Binder, Alexander; Bockmayr, Michael; Hägele, Miriam; Wienert, Stephan; Heim, Daniel; Hellweg, Katharina; Ishii, Masaru; Stenzinger, Albrecht; Hocke, Andreas C.; Denkert, Carsten; Müller, Klaus-Robert; Klauschen, Frederick
Morphological and molecular breast cancer profiling through explainable machine learning. *Nature Machine Intelligence* , vol. 3. pp.355- 366, 2021

Boubekki, Ahcene; Kampffmeyer, Michael; Brefeld, Ulf; Jenssen, Robert
Joint optimization of an autoencoder for clustering and embedding. *Machine Learning*, vol.110. pp.1901-1937, 2021

Choi, Changkyu; Kampffmeyer, Michael; Handegard, Nils Olav; Salberg, Arnt Børre; Brautaset, Olav; Eikvil, Line; Jenssen, Robert
Semi-supervised target classification in multi-frequency echosounder data. *ICES Journal of Marine Science*, vol.78.(7) pp.2615-2627, 2021

Dong, Nanqing; Kampffmeyer, Michael; Voiculescu, Irina
Self-supervised Multi-task Representation Learning for Sequential Medical Images. *Lecture Notes in Computer Science* (LNCS), vol. 12977. pp.779-794, 2021

Handegard, Nils Olav; Algrøy, Tonny; Eikvil, Line; Hammersland, Hege; Tenningen, Maria; Ona, Egil
Smart Fisheries in Norway: Partnership between Science, Technology, and the Fishing Sector. *Journal of Ocean Technology*, vol.16.(2), pp.11-18, 2021

Handegard, Nils Olav; Eikvil, Line; Jenssen, Robert; Kampffmeyer, Michael; Salberg, Arnt Børre; Malde, Ketil
Machine Learning + Marine Science: Critical Role of Partnerships in Norway. *Journal of Ocean Technology*, vol.16.(3) pp.1-9, 2021

Trosten, Daniel Johansen; Jenssen, Robert; Kampffmeyer, Michael
Reducing Objective Function Mismatch in Deep Clustering with the Unsupervised Companion Objective. *Proceedings of the Northern Lights Deep Learning Workshop*, vol.2, 2021

Johansen, Thomas Haugland; Sørensen, Steffen Aagaard; Møllersen, Kajsa; Godtliebsen, Fred
Instance Segmentation of Microscopic Foraminifera. *Applied Sciences*, vol.11. (14), 2021

Kuttner, Samuel; Wickstrøm, Kristoffer Knutsen; Lubberink, Mark; Tolf, Andreas; Burman, Joachim; Sundset, Rune; Jenssen, Robert; Appel, Lieuwe; Axelsson, Jan
Cerebral blood flow measurements with O-water PET using a non-invasive machine-learning-derived arterial input function. *Journal of Cerebral Blood Flow and Metabolism*, pp. 1-13, 2021

Liu, Qinghui; Kampffmeyer, Michael; Jenssen, Robert; Salberg, Arnt Børre
Self-constructing graph neural networks to model long-range pixel dependencies for semantic segmentation of remote sensing images. *International Journal of Remote Sensing*, vol.42.(16) pp.6184-6208, 2021

Luppino, Luigi Tommaso; Kampffmeyer, Michael; Bianchi, Filippo Maria; Moser, Gabriele; Serpico, Sebastian Bruno; Jenssen, Robert; Anfinsen, Stian Normann
Deep image translation with an affinity-based change prior for unsupervised multimodal change detection. *IEEE Transactions on Geoscience and Remote Sensing* 2021

Sun, Jiamei; Lapuschkin, Sebasian; Samek, Wojciech; Binder, Alexander
Explain and improve: LRP-inference fine-tuning for image captioning models. *Information Fusion*, vol.77. pp.233-246, 2021

Trosten, Daniel Johansen; Løkse, Sigurd Eivindson; Jenssen, Robert; Kampffmeyer, Michael
Reconsidering Representation Alignment for Multi-View Clustering. *Computer Vision and Pattern Recognition*, pp.1255-1265, 2021

Uteng, Stig; Quevedo, Eduardo; Callico, Gustavo M.; Castaño, Irene; Carretero, Gregorio; Almeida, Pablo; Garcia, Aday; Hernandez, Javier A.; Godtliebsen, Fred
Curve-Based Classification Approach for Hyperspectral Dermatologic Data Processing. *Sensors*, vol.21.(3) pp.1-13, 2021

Xie, Zhenyu; Huang, Zaiyu; Zhao, Fuwei; Dong, Haoye; Kampffmeyer, Michael; Liang, Xiaodan
Towards Scalable Unpaired Virtual Try-On via Patch-Routed Spatially-Adaptive GAN. *Advances in Neural Information Processing Systems*, (NeurIPS) 2021

Yeom, Seul-Ki; Seegerer, Philipp; Lapuschkin, Sebastian; Binder, Alexander; Wiedemann, Simon; Müller, Klaus-Robert; Samek, Wojciech
Pruning by explaining: A novel criterion for deep neural network pruning. *Pattern Recognition*, vol.115, 2021

Yu, Shujian; Alesiani, Francesco; Yu, Xi; Jenssen, Robert; Principe, Jose C
Measuring Dependence with Matrix-based Entropy Functional. *Proceedings of the AAAI Conference on Artificial Intelligence* 2021

Zhao, Fuwei; Xie, Zhenyu; Kampffmeyer, Michael; Dong, Haoye; Han, Songfang; Zheng, Tianxiang; Zhang, Tao; Liang, Xiaodan
M3D-VTON: A Monocular-to-3D Virtual Try-On Network. *IEEE International Conference on Computer Vision* (ICCV), 2021

Reports

Handegard, Nils Olav; Andersen, Lars Nonboe; Brautaset, Olav; Choi, Changkyu; Eliassen, Inge Kristian; Heggelund, Yngve; Hestnes, Arne Johan; Malde, Ketil; Osland, Håkon; Ordonez, Alba; Patel, Ruben; Pedersen, Geir; Umar, Ibrahim; Engeland, Tom Van; Vatnehol, Sindre
Fisheries acoustics and Acoustic Target Classification - Report from the COGMAR/CRIMAC workshop on machine learning methods in fisheries acoustics. Bergen: Havforskningsinstituttet, 25 s. Rapport fra havforskningen (2021 - 25)

PhD defenses, students working on projects in the centre with financial support from other sources

Thomas Haugland Johansen
25.06.2021
Leveraging Computer Vision for Applications in Biomedicine and Geoscience

Miguel Angel Tejedor Hernandez
07.05.2021
Glucose Regulation for In-Silico Type 1 Diabetes Patients Using Reinforcement Learning

Samuel Kuttner
28.05.2021
Advancing Quantitative PET Imaging with Machine Learning

Qinghui Liu
8.12.2021
Advancing Land Cover Mapping in Remote Sensing with Deep Learning

Researchers involved in the centre 2021

Innovation area (IA)
IA1 Medicine and health
IA2 Marine science
IA3 Energy
IA4 Earth observation

Research Challenge (R)
RC1 Learning from limited data
RC2 Incorporating context and dependencies
RC3 Quantifying confidence and uncertainty
RC4 Providing explainability and reliability

Key researchers

Name	Institution	Main research area
Robert Jenssen	UiT	IA1 - IA4, RC1 – RC4
Lars Ailo Bongo	UiT	IA1, RC1
Fred Godtliebsen	UiT	IA1, IA3, RC3
Michael Kamffmeyer	UiT	IA1, IA2, RC1, RC4
Stian Arnfinsen	UiT	IA3, RC2
Camilla Brekke	UiT	IA4, RC1, RC2
Andrea Marioni	UiT	IA4, RC1, RC2
Benjamin Ricaud	UiT	IA1. IA3, RC2
Shujian Yu	UiT	RC1, RC4
Anne Solberg	UiO	IA1 - IA4, RC1 – RC4
Alexander Binder	UiO	IA1, RC4
Andreas Austeng	UiO	IA2
Geir Storvik	UiO	RC3
Line Eikvil	NR	IA1 - IA4, RC1 – RC4
Arnt-Børre Salberg	NR	IA2, IA4
Marit Holden	NR	IA1, IA3
Rune Solberg	NR	IA4
Alba Ordonez	NR	IA3, IA2
Anders U. Waldeland	NR	IA3
Olav Brautaset	NR	IA2. IA1
Ingrid Utseth	NR	IA2, IA3
Amund H. Vedal	NR	IA1, IA2
Fredrik A. Dahl	NR	IA1
Are F. Jenssen	NR	IA4
Izzie Yi Liu	NR	IA4, IA2
Øystein Rudjord	NR	IA4
Øivind D. Trier	NR	IA4

Visiting researchers

Name	Institution	Topic
Ane Blazquez Garcia	University of the Basque Country	Anomaly detection for time series analysis and self-supervised learning

Postdoctoral researchers working on projects in the centre with financial support from other sources

Name	Institution	Topic
Ahcene Boubekki	UiT	Deep clustering and representation learning
Luigi Tommaso Luppino	Tromsø Research Foundation	Developing deep learning methodologies for medical image analysis, with particular focus on dynamic PET applications
Sarina Thomas	RCN - EchoAI	Automatic interpretation of cardiac ultra sound images
Sigurd Løkse	RCN	Deep Learning from Electronic Health Records under Learning Constraints

PhD students working on projects in the centre with financial support from other sources

Name	Institution	Topic
Thomas Haugland Johansen	UiT	Leveraging Computer Vision for Applications in Biomedicine and Geoscience
Changkyu Choi	RCN	Advancing Semi-supervised Learning for Non-standard Images Automatic interpreta-tion of cardiac ultrasound images
Daniel Johansen Trosten	RCN	Learning in the presence of limited labels
Jørgen A. Lund	RCN/DIPS	Data driven pathways: augmenting clinical process design with decision support
Jørgen A. Agersborg	UiT	Combining optical and radar remote sensing data for arctic tundra vegetation analysis

PhD students working on projects in the centre with financial support from other sources

Name	Institution	Topic
Kristoffer Knutsen Wickstrøm	UiT	Advancing Trustworthy Deep Learning with Emphasis on Data-Driven Healthcare
Marit Dagny Kristine Jenssen	UiT	Development of decision support tools for patients by learning from actual chronic pain patient outcomes
Miguel Angel Tejedor Hernandez	Tromsø Research Foundation	Glucose Regulation for In-Silico Type 1 Diabetes Patients Using Reinforcement Learning
Per Roald Leikanger	UiT	Autonomous navigation in (the animal and) the machine
Rajendra Sapkota	UiT	Analysis of Noctilucent Clouds with Machine Learning
Samuel Kuttner	UiT	Advancing Quantitative PET Imaging with Machine Learning
Sara Björk	UiT	Biomass estimation under dataset shift
Srishti Gautam	UiT	Advancing self-explainable deep learning
Stine Hansen	UiT	Advancing Machine Learning for Semantic Medical Image Segmentation with Limited Labels
Brian Liu	NR	Advancing Land Cover Mapping in Remote Sensing with Deep Learning
Børge Solli Andreassen	UiO	Image Fusion for Guiding Cardiac Intervention using Deep Learning
Tollef Jahren	UiO	-
Kristine Baluka Hein	UiO	Interpreting Deep Learning for Images
Ghadi Al Hajj	UiO	Improving the generalization of machine learning models in medical image and immune receptor sequence analysis through the incorporation of domain priors and constraints

Statement of accounts

Statement of Accounts (All figures in 1000 NOK)	2021
Funding	
The Research Council	8183
The host institution (UiT)	3733
Research partners*	1530
Enterprise partners*	2936
Public partners*	6450
Total	22 832
Costs	
The host institution (UiT)	6705
Research partners	7507
Enterprice partners	2514
Public partners	5184
Equipment (UiT)	922
Total	22 832
Cost per Innovation area	
Medicine & health	8434
Marine sciences	5985
Energy	2438
Earth observation	2720
Sci. Coordination	2333
Equipment	922
Total	22 832

*UiO, NR
** Equinor, GE vingmed, KSAT, Terratec
*** Havforskningsinstituttet, HN IKT, Kreftregisteret, UNN

Visual Intelligence performance 2021

	Total	Male	Female
Dissemination measures for the general public			
Popular science publications	3		
New publication in the media	9		
Dissemination measures for users			
Reports, articles, presentations held at meetings/ conferences for project target groups	38		
Industry-oriented R&D results	10		
New/improved methods/models/prototypes finalized			
Publications	18		
Scientific publications	1		
Reports			
Personell	4	3	1
Postdocs funded by associated projects	5	5	0
PhD Funded by the Centre	19	14	5
PhD funded by associated projects	28	21	7
Guest Scientists	1	0	1
Degrees			
PhD Thesis	4		
Master thesis	7		

Contact information

E-mail:
Visual-Intelligence@uit.no

Contact form:
https://www.visual-intelligence.no/contact

Web page:
www.visual-intelligence.no

Visiting address:
Siva Innovasjonssenter Tromsø (Forskningsparken 1)
Sykehusvegen 21
9019 Tromsø

Postal Address:
Visual Intelligence
Department of Physics and Technology
P.O. box 6050 Langnes
NO-9037 Tromsø, Norway

Robert Jenssen
Centre Director
robert.jenssen@uit.no

Inger Solheim
Centre administrative coordinator
inger.solheim@uit.no

VISUAL INTELLIGENCE

sfi Centre for Research-based Innovation

NORGES ARKTISKE UNIVERSITET • UIT •

UNIVERSITAS OSLOENSIS • MDCCCXI •

NR