



Evaluation of Mathematics, ICT and Technology (EVALMIT) 2023–2024

Self-assessment for research groups

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Research group: Digital Signal Processing and Image Analysis (DSB)

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1 Organisation and strategy

1.1 Research group's organisation

With a staff of more than 400, The UiO Department of Informatics (IFI) is a “powerhouse” for informatics training and research in Northern Europe. It is the largest such unit in Norway and the one with the strongest international rankings. Around a comprehensive core in computer science, IFI interprets informatics in substantial breadth: from microelectronics and signal processing to participatory design and digital innovation. In 2023, IFI hosts five BSc and eight MSc study programmes, with close to 2500 students. The department is organized in four thematic sections, each of which comprises 2–5 research groups. Our group, *Digital Signal Processing and Image Analysis* (DSB) is one out of five research groups in the Section for Machine Learning.

DSB was formally established in 1998 when the activities in data analysis, signal processing and image analysis were merged into one group. A few years later, the researchers in data analysis spun out of the group. Ever since, the main DSB group research foci have been on image analysis and machine learning, as well as on signal processing with emphasis on acoustic imaging applications. DSB has a broad application domain expertise in computer vision, medical ultrasound, sonar and seismics, image texture analysis, and remote sensing. A great deal of the research is related to health and medical related application.

The group members are permanent employees (Professors, Assoc. Professors, Senior Engineer), temporary employees (Adjunct Professors, Adjunct Assoc. Professors, Postdocs, PhDs), and master students. The group manager role rotates between the permanent employees and currently Assoc. Professor Sven Peter Näsholm manages the group. In addition, Professor Andreas Austeng is the manager of the Machine Learning Section. DSB is well-functioning with daily lunches, weekly status meetings and research seminars, journal clubs, and additional addition to social activities (e.g., group dinners, joint excursions, and game nights). Formal and informal information sharing within the group takes place through e-mail lists and Mattermost chat channels.

In October 2022, the 24 DSB members were:

- Professors: Andreas Austeng, Anne Solberg
- Associate Professors: Adín Ramírez Rivera, Sven Peter Näsholm
- Adjunct Professors: Håvard E.G. Danielsen (main employer: Oslo University Hospital), Roy E. Hansen (main employer: Norwegian Defence Research Establishment), Eigil Samset (main employer: GE Vingmed Ultrasound)
- Adjunct Associate Professors: Alan J. Hunter (main employer: University of Bath), Are F.C. Jensen (main employer: the Norwegian Computing Center), Andreas Kleppe (main employer: Oslo University Hospital)
- Senior Engineer: Yücel Karabıyık
- Postdoctoral fellows: Ole Marius Hoel Rindal, Sarina Thomas
- PhD fellows: Marius Aasan, Håvard Kjellmo Arnestad, Edward Fabian Bull, James Benedict Claxton, Gabor Gereb, Kristine Baluka Hein, Dharani Dhar Maddali, Seyed Mohammad Reza Sajadi, Martine KBH Tan, Dhananjay Tomar

As of December 2023, the 25 DSB group members are:

- Professors: Andreas Austeng, Anne Solberg
- Associate Professors: Ali Ramezani-Kebrya, Adín Ramírez Rivera, Sven Peter Näsholm
- Adjunct Professors: Roy E. Hansen (main employer: Norwegian Defence Research Establishment), Eigil Samset (main employer: GE Vingmed Ultrasound)

- Adjunct Associate Professors: Are F.C. Jensen (main employer: the Norwegian Computing center), Andreas Kleppe (main employer: the Oslo University Hospital), Ole Marius Hoel Rindal (main employer: Sonair AS)
- Senior Engineer: Yücel Karabıyık
- Postdoctoral research fellows: Sarina Thomas, Mahsa Sotoodeh Ziksari
- PhD fellows: Marius Aasan, Håvard Kjellmo Arnestad, Amir Inaamullah Arfan, Edward Fabian Bull, Vilde Bøe, James Benedict Claxton, Gabor Gereb, Seckin Polat, Sufayan Mulani, Martine KBH Tan, Dhananjay Tomar, Zhiyuan Wu

The research focus prior to 2012 was on combining acoustic imaging and image analysis in joint cross-disciplinary projects. Early in the period 2012–2022, a lot of effort was put into writing proposals to national funding agencies and EU to attract grants both for smaller and larger collaborative projects. The result was an extensive set of collaborations with industry and other research institutes. This in turn gave rise to several externally funded projects that set the focus for the concrete research problems tackled in the years to follow.

In the period 2012–2022, 28 PhDs have been awarded (5 female), and a total of 14 Postdocs research fellow (3 female) were hosted by DSB.

A key aspect is the generation shift that DSB has undergone on the permanent staff side. In 2019, the group had 4 experienced permanent full Professors and no permanent Associate Professor. As of 2022, the group has grown and shifted to have 2 full Professors and 3 Associate Professors.

Table 1. List of number of personnel by categories. We list the employees as of October 2022.

	Position by category	No of researcher per category	Share of women per category (%)	No of researchers who are part of multiple (other) research groups at the admin unit	No of temporary positions
No of Personnel by position	Professor (1013)	2	50%	-	-
	Associate Prof. (1011)	2	0%	-	-
	Senior Engineer (1181)	1	0%	-	-
	Adjunct Professor (1013)	3	0%	-	3
	Adjunct Associate Professor (1011)	4	0%	-	4
	Postdoctoral research fellow (1352)	2	50%	-	2
	Doctoral research fellow (1017)	10	20%		10

1.2 Research group's strategy

a) Describe the research group's main goals, objectives, and strategies to obtain these (e.g., funding, plans for recruitment, internationalisation, etc.) within the period 2012-2022.

The main strategic goals of the group in 2012-2022 can be summarized as follows:

- Maintaining the position as a major Norwegian research group in machine learning for imaging.
- Remaining as a principal Norwegian research group in acoustic imaging and array signal processing across application domains.

These goals are achieved through:

- Developing the teaching offers in machine learning, image analysis, array signal processing, and acoustic imaging. Link these courses to relevant study programmes and actively contribute to the development of these programmes.
- Continuing to deliver internationally acknowledged research output in our fields, both in terms of more basic-research oriented output and in terms of applied research and innovation contributions.
- Maintaining and increasing the external project funding, addressing national and international funding agencies as well as further developing industry-related collaborations.
- Accommodating PhD and Postdoc research fellows by securing grants from both external and internal funding sources.

Succeeding in a faculty staff generation shift

Until 2019, the DSB permanent faculty staff consisted of four experienced full professors and no associate professor. In 2022, with Professor Fritz Albregtsen having retired, and Professor Sverre Holm having moved to another Department and soon retiring, the group instead had two full professors and two recently hired associate professors. As of 2023, another young associate professor has joined the group. We reckon that we have handled the initial phase of this generation shift well. Currently, DSB is in a phase of further research and teaching renewal and consolidation.

b) Please describe the benchmark of the research group. The benchmark for the research group should be written by the administrative unit in collaboration with the research group. The benchmark can be a reference to an academic level of performance (national or international) or to the group's contributions to other institutional or sectoral purposes.

Abbreviations used when referring to Department strategic and action plan documents:

- The IFI 2019-2021 Action plan (*handlingsplan*) is designated **AP19**.
- The IFI 2014-2017 Strategic plan (*strategisk plan*) is designated **SP14**.
- The IFI 2010-2014 Strategic plan (*strategisk plan*) is designated **SP10**.
- The Faculty of Mathematics and Natural Sciences strategy towards the year 2030 is designated **MN30**.

Benchmark 1: Extensive national & international projects and attracting external funding

*Related to: **AP19**, where key contents in its Research section underlines growth in externally funded larger initiatives; **SP14**, where a separate section on Externally funded research emphasizes growth in externally funded large projects nationally and internationally; **SP10**, where the External funding section states that IFI will work towards increasing the amount of large externally funded projects.*

DSB has succeeded in partnering in large national and international center projects ([SFI](#), [SFF](#), and Research Council of Norway ICT [Lighthouse projects](#)). As highlighted in Table 4, DSB has also attracted

funding as partner of prestigious basic research funding through the RCN FRIPRO programme (the [AIR](#) project granted in 2022), as well as from the EU Horizon programmes (the [FORCE](#) project). The emphasis on external funding is reflected by the fact that 9 of the 11 PhD and Postdoc research fellow grants are externally funded (October 2022). In the evaluation period, the following larger-scale projects have been conducted, started, or recently been granted funding: [CIUS](#), [DoMore!](#), [Visual Intelligence](#), [INTEGREAT](#).

Benchmark 2: Research & collaboration in the thematic areas Medicine & health and Machine learning / artificial intelligence

Related to: MN30, which has Digitalisation and computational science as one of its four thematic priorities, where data science, computational science, and machine learning are explicitly mentioned as foci of the faculty; AP19, which identifies machine learning / artificial intelligence as well as Societal challenges in health & energy as two out of five prioritized research subject areas; SP14, where medicine & health and Energy & environment are appointed as IFI overarching tasks for research and solving societal challenges. Medicine & health was also denoted one of two prioritized application areas – where image analysis and ultrasound were also explicitly mentioned; SP10, where informatics in Medicine & health was listed as one out of four strategic focus areas.

As reflected by our project portfolio and body of publications, the greatest share of the group's research in 2010-2022 has been related to either medicine & health or machine learning / artificial intelligence, or both. For example, 8 out of the 10 PhD research fellows in December 2022 had their research projects within these areas.

Benchmark 3: Reshaping the machine learning and acoustics related course offerings

Related to: The overall mission of providing course offerings of great relevance to society, industry, and research.

The DSB course offerings are in a reshaping process. The course in Deep learning for image analysis remains very popular and is substantially revised in 2023 – 2024. This course is now offered as an MSc/BSc course, instead of as a PhD/MSc course. This makes the course an even better fit to the Department and Faculty landscape of machine learning course offerings. Moreover, a new course in Advanced deep learning for image analysis is now provided, while a previous course in classical image analysis has been discontinued.

Similarly, the course offering in the signal processing domain is modernized where a new course in statistical signal processing has replaced the previous course “Digital signal processing II,” while an increasingly popular project-based course in Ultrasound Imaging has replaced the previous course in Acoustic imaging. This way, the full DSB course portfolio is now better targeting the MSc and PhD student needs and is becoming more coherent. Subsection c) below lists the DSB course portfolio.

c) Describe the research group contribution to education (master's degree and/or PhD)

In the period 2018–2022 – characterized by a faculty generation shift in the group – DSB has graduated 12 PhD and 21 MSc candidates (2.4 PhD and 4.2 MSc per year on average).

The DSB group has a long tradition of linking computer science and scientific computing in inter-department study programmes. Together with the Department of Physics, DSB has established the ELITE (Electronics, Informatics and Technology) MSc programme. Together with several departments at the faculty, we have established the Computational Science MSc programme. This is an MSc programme that involves most departments at the faculty. Together with the Department of Mathematics, we take part in the Data Science MSc programme.

As a research group at UiO with a long history of working with machine learning – starting out from pattern recognition research in image analysis since the 1980s – DSB established the first large course

in deep learning at UiO in 2016. This was expected to become a small niche course attracting mainly our own students, but it turned out to be one of the department's largest MSc/PhD courses, attracting more than 100 enrolled students. In cooperation with StartupLab and NR/SINTEF, DSB has also offered several short courses targeting external and industry participants.

DSB is one of the driving forces behind the establishment of a new bachelor programme in AI, soon to be hosted by IFI. The group is responsible for these six MSc and PhD courses – all corresponding to 10 ECTS credits: Advanced deep learning for image analysis (MSc/PhD); Array signal processing (MSc/PhD); Deep learning for image analysis (MSc); Digital signal processing (MSc); Statistical signal processing (MSc/PhD); Ultrasound imaging (MSc). All our courses involve DSB research related aspects.

d) Describe the **support the host institution provides** to the research group (i.e., research infrastructure, access to databases, administrative support, etc.)

Machine learning and signal processing projects involve computationally intensive algorithms, and we use several high-performance computing (HPC) resources and servers to cover these needs. See Section 1.5 b) for further HPC usage details, in particular regarding national and international HPC resources usage.

While the CPU servers dedicated to our group are utilized mostly for signal processing research and wave-propagation simulation, we use GPU resources for machine learning projects. The CPU servers are maintained by the Department IT support and used by researchers and master students, while our (limited) own GPU servers are maintained by the University IT Department. These GPU resources are mainly used in first-level prototyping and for running small-scale experiments. Previously, the group also used a HTCondor system that took advantage of the computational resources of 200+ Desktop PCs when these were idle.

The group also benefits from the senior engineers for teaching and research tasks related to laboratory work and numerical experiments. The group has two laboratories equipped with ultrasound scanners, water tanks used for acoustic measurements and several diverse electronic instruments which are maintained by the group's senior engineer.

The local IT group supports our general IT needs and assists with infrastructure and software.

1.3 Relevance to the institutions

Describe the role of the research group within the organisation. Consider the group's contribution towards the institutional strategies and objectives and relate the group's benchmark to these.

The project portfolio as well as PhD and MSc projects are largely addressing applications in medicine and health. This is well aligned with the IFI 2014-2017 strategic plan where one out of two defined *Priority application areas* is *Medicine and health*. Likewise, the IFI action plan 2019-2021 defined *Health and Energy* as areas of central contribution – see also Section 1.2 b).

Two out of three of the Associate Professors that joined DSB in the evaluation period have their research focused on machine learning related topics. Positions in machine learning related domains have been prioritized by the IFI board, which is also in line with the DSB overall research objectives and longer-term project portfolio.

At the department, DSB has initiated major courses in deep learning that attract students from several study programmes, also outside of IFI. In the earlier phase of the EVALMIT period, we also initiated – together with other research groups interested machine learning across the department –

new cooperations in terms of a joint forum with central Machine Learning oriented faculty members, as well as a common seminar. This was an important factor behind the establishment of the current Machine Learning Section.

DSB also contributed to the establishment of the [Centre for Computational and Data Science](#) (dScience) at UiO and actively takes part in this centre since its conception. Prof. Anne Solberg is a member of the dScience council.

DSB is, and has been, active in several different forums at the Faculty and Department. This includes the recently launched [IFI Green Council](#) where Assoc. Prof. Ramezani-Kebrya is a member. We have representatives in several study program boards: Electronics, Informatics, and Technology (MSc and BSc); Computational Science (MSc); Data Science (MSc). Prof. Anne Solberg is also a member of the IFI Education committee. Prof. Andreas Austeng was an elected member of the IFI board during parts of the EVALMIT period in the roles of substitute member 2012–2016 and as a full board member 2017–2020.

1.4 Research group's resources

Describe the funding portfolio of the research group for the last five years (2018 – 2022).

The RCN Centre for Research-based Innovation (SFI) programme is the main source of this funding through the Visual Intelligence and the CIUS projects (see Table 4).

The DSB funding portfolio consists to great extent of external grants from the RCN. Seven out of the 10 PhD and two out of two Postdoctoral research fellows by October 2022 are funded from external agencies.

In addition, there were six PhD research fellows with DSB affiliation, but employed by industry companies (Equanostic AS, Kongsberg Maritime, and GE Vingmed Ultrasound). These are supervised by universities in collaboration with industry and the candidates are enrolled in the same PhD programme as the DSB fellows on the IFI payroll. (Note that the budgets covering these grants funding the externally employed PhD research fellows are not included in Table 2.)

Table 2. The sources of R&D funding for the research group in the period 2018–2022.

	2018 (kNOK)	2019 (kNOK)	2020 (kNOK)	2021 (kNOK)	2022 (kNOK)
Basic funding	6507	8078	6996	6447	5936
Funding from industry and other private sector sources					
Commissioned research for public sector					
Research Council of Norway	6920	6920	6017	9331	7893
Grant funding from other national sources					
International funding, e.g., NIH, NSF, EU framework programmes	1406	1406	1531	125	125
Other					

1.5 Research group's infrastructures

Research infrastructures are facilities that provide resources and services for the research communities to conduct research and foster innovation in their fields. [These](#) include major equipment or sets of instruments, knowledge-related facilities such as collections, archives or scientific data infrastructures, computing systems communication networks Include both internal and external infrastructures.

a) Describe which national infrastructures the research group manages or co-manages.

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b) Describe the most important research infrastructures used by the group.

The group has two laboratories equipped with both clinical and research graded ultrasound scanners (Verasonics Vantage 256 and GE Vivid E95), as well as with several types of ultrasound probes for 2D and 3D imaging. The group had one GE System Five medical ultrasound scanner which has now become obsolete, but which was in extensive use during the early EVALMIT period. In addition, the group has a custom-built large water tank used for sonar measurements, one ONDA AIMS III Hydrophone Scanning System used for medical ultrasound related projects, and an additional smaller water tank used for ultrasound measurements. Several supplemental hydrophones with various frequency band sensitivities are available in our lab. DSB owns general-purpose ultrasound and elastography phantoms that are used for in vitro studies with the ultrasound scanners. A HoloLens Augmented Reality system is used for visualization method development in medical ultrasound.

For the computational tasks, the group utilizes CPU and GPU resources available at the local, university, national and international levels. The group has two dedicated servers for CPU- and RAM-demanding numerical experiments and computation, typically used in signal processing and wave propagation studies. The [Fox](#) HPC cluster is used mostly as a GPU resource for code development and for training machine learning models. In addition, the group has projects and resource allocations in the national HPC resources hosted by [Sigma2](#), as well as in the European flagship HPC system [LUMI](#).

1.6 Research group's cooperations

Table 3. Reflect on the current interactions of the research group with other disciplines, non-academic stakeholders and the potential importance of these for the research (e.g., informing research questions, access to competence, data and infrastructure, broadening the perspectives, short/long-term relations).

Interdisciplinary (within and beyond the group)	The DSB research covers the creation of images – all the way from upstream processing of raw sensor data to image reconstruction, to the analysis, interpretation, and enhancement of the final images. Extraction of information from and interpretation of images is performed using computer vision and machine learning based approaches. Research is also performed in collaboration with downstream users, such as medical experts who make diagnoses from the images. All these aspects of the research require significant interdisciplinary collaboration. In both image reconstruction and image analysis research, the algorithmic research and development performed by DSB is actively performed in
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	collaboration with partners from other subdomains and domains. Acoustic imaging is performed both in medical ultrasound, sonar, and atmospheric infrasound. The group works closely with acoustic imaging system manufacturers such as GE Vingmed Ultrasound and Kongsberg Maritime in projects like CIUS, MEDIMA, and Visual Intelligence. The image analysis research is carried out on acoustic images from medical ultrasound, sonar, and seismics, as well as on satellite and microscopy images. The group collaborates closely with users of imaging equipment through projects such as CIUS, MEDIMA, DoMore, and Visual Intelligence. In a recently started interdisciplinary initiative, Brainsight, researchers in both signal processing and machine learning from DSB as well as from the Scientific Computing and Machine Learning research group are working on unravelling links between human perception of images and the measured brain activities. This is a new collaboration with the Institute of Basic Medical Sciences.
Collaboration with other research sectors, e.g., higher education, research institutes, health trusts and industry	The DSB group has extensive collaboration with Norwegian research institutes, universities, and industry. Most collaborative projects deal with practical challenges with significant industrial and societal relevance. As also reflected in the body of publications and co-authorships, DSB works closely with Norwegian research institutes such as NR, FFI, NGI, NORSAR, and SINTEF in projects like Visual Intelligence, CIUS, AIR, ACT4Storage, and AutoActive. We have close collaboration with NTNU and UiT through the SFI's CIUS and Visual Intelligence, but also with health institutions such as the Radium Hospital, Rikshospitalet, and UNN through projects such as DoMore, CIUS, and Visual Intelligence. Norwegian industry partners such as GE Vingmed Ultrasound, Kongsberg Maritime, Equinor, are involved in CIUS, Visual Intelligence, Act4Storage, INIUS, INCUS, DoMore!, and EchoAI.
Transdisciplinary (including non-academic stakeholders) <i>Transdisciplinary research involves the integration of knowledge from different science disciplines and (non-academic) stakeholder communities with the aim to help address complex societal challenges</i>	The research group has an algorithmic focus related to challenges such as improved image quality in image reconstruction, and more precisely interpretation and medical diagnoses in image analysis. Through collaboration with problem owners, we have extensively participated in transdisciplinary research. For three decades, DSB has collaborated with the Radium Hospital on digital pathology with the aim of improving diagnosis and prognosis for cancer patients. We recently completed the 5-year project DoMore! in which we contributed to the digitization of pathology and paved the way for the transition from digital pathology to in silico pathology, in addition to introducing AI and deep learning into tissue diagnostics. Together with GE Vingmed Ultrasound and other CIUS partners, we have participated in the development of improved image formation and image analysis for ultrasound imaging of the heart. The group has is active in the research niche related to gas detection using sonar data. In the EVALMIT period, Carbon Dioxide Capture and Storage (CCS) has become even more societally relevant nationally and internationally. This research activity has led to participation in two industry-supported RCN projects focusing on the monitoring of CCS sites. Capturing and storing CO₂ is a key component to reach our climate goals, and DSB hence takes active part in this endeavor.

2 Research quality

2.1 Research group's scientific quality

Describe the research profile of the group and the activities that contribute to the research group's scientific quality. Consider how the group's work contributes to the wider research within the group's field nationally and internationally.

DSB publishes fundamental and applied research results in a wide spectrum of peer-reviewed journals and conferences. In the EVALMIT period, this also includes high-profile outlets such as Physical review letters, The Lancet, and Nature Reviews Cancer.

The DSB research activity in signal processing is focused on theory and applications that exploit signals from sensor arrays. In essentially all these applications, propagating waves are used to probe different media or sources. These signals are typically picked up by arrays of sensors, each recording a time signal. Key applications are in medical ultrasound, sonar, and atmospheric infrasound DSB encompasses expertise in the wave propagation physics, the acoustical imaging systems, as well as in the signal processing that is applied to reconstruct images based on the signals. The group has pioneered the transformation of adaptive beamforming algorithms – which were originally developed to determine direction-of-arrival for passive far-field narrow-band signals – to be used in near-field broadband pulse-echo image reconstruction, in particular for medical ultrasound. A great share of the algorithm development first takes place on simulated scenarios before it is further assessed and elaborated using real-world data. Major contributions to the wider international research community include the open-source UltraSound Toolbox (USTB) signal processing package which has been developed by DSB and partners. This framework is used in academic and industry research world-wide – see Table 7 DSB researchers have also contributed to the design of [medical ultrasound image reconstruction challenge](#) competitions organized by the IEEE Ultrasonics, Ferroelectrics, and Frequency Control Society in 2016.

The DSB research activity in image analysis has a focus on automatic methods for extracting information from images. In the last decade, deep learning has revolutionized this field and DSB is in the forefront of this transformation. The research focus has shifted from classical image analysis and pattern recognition towards deep learning and the development of methods that in a best way circumvent limitations like limited training data, are able to estimate confidence and quantify uncertainty, and provide explainable and reliable predictions. Key application areas are medical imaging, sonar, seismic, as well as in remote sensing. These research activities are inherently data-driven and access to relevant datasets is gained through project collaboration partners and to some extent using openly available datasets.

A strength of the group is in its well-established link to research institutions and industry. This is heavily reflected in the project portfolio and collaboration ecosystem. The group and its researchers in signal processing, image analysis, are partners of centres of research-based innovation: [Centre for Innovative Ultrasound Solutions \(CIUS\)](#) and [Visual Intelligence](#). In addition, we are part of the newly founded centre of excellence. [Integrate – the Norwegian Centre for Knowledge-driven Machine Learning](#) and we were a main research partner in the Lighthouse project [DoMore!](#)

Please add a link to the research group's publication list at the research group's website:

<https://www.mn.uio.no/ifi/english/about/strategy/evalmit/dsb.html>

Table 4. List of projects

Instructions: Please select 5-10 projects you consider to be representative/the best of the work in the period 1 January 2012 – 31 December 2022. The list may include projects lead by other institutions nationally or internationally.

Project 1: [Research Council of Norway (RCN) Centre for Research-based Innovation, SFI] CIUS – Centre for Innovative Ultrasound Solution for health care, maritime, and oil & gas (2015 – 2024)	Project owner	NTNU, Norwegian University of Science and Technology
	Total budget and share allocated to research group	438 MNOK total, DSB share 13.5 MNOK
	Objectives and outcomes	CIUS (https://www.ntnu.edu/cius/) is a centre for research-based innovation financed by the RCN and Norwegian industry. Its overall goals are: 1. To be a world-leading centre for research and innovation in next-generation ultrasound imaging, improving patient care, harvesting of ocean resources, and for environmental monitoring and safety. 2. To extend and strengthen the innovation culture with emphasis on rapid translation from idea to practical applications and solutions needed to facilitate new growth for the industries. 3. To be the main educational and knowledge centre for ultrasound technology to ensure sufficient competence and recruitment needed by Norwegian industries, academia, and the healthcare sector. The centre comprises a total of four academic research partners and 13 corporate partners.
Project 2: [RCN Centre for Research-based Innovation, SFI] Visual Intelligence (2021 – 2028)	Project owner	University of Tromsø
	Total budget and share allocated to research group	Total from the research council: 96 MNOK, DSB share 35 MNOK
	Objectives and outcomes	Visual Intelligence (https://www.visual-intelligence.no/) Our main objective is to unlock the potential of visual intelligence across the main innovation areas medicine and health, marine science, energy sector, and earth observation by enabling the next generation deep learning methodology for extracting knowledge from complex image data.

		The secondary objectives aim at this through analysis of complex imagery for real-life applications with: • Solutions for learning from limited data. • Solutions for exploitation of context, dependencies, and prior knowledge. • Solutions for estimation of confidence and quantification of uncertainties. • Solutions for explainable and reliable predictions.
Project 3: [Research Council of Norway Lighthouse project] DoMore! In silico Pathology – Improving diagnostics by utilizing Big Data and software-driven automation of pathology (2016 – 2021)	Project owner	Institute for Cancer Genetics and Informatics, the Oslo University Hospital
	Total budget and share allocated to research group	122 MNOK total, DSB share 11 MNOK from the RCN
	Objectives and outcomes	The DoMore! project (https://www.domore.no/) was in 2016 selected as one of the RCN Lighthouse projects aiming to solve large societal challenges using cutting-edge technology. Understanding how a tumour will develop is essential for the proper treatment of cancer patients. A range of artificial intelligence products based on the DoMore!-research will be available to assist clinicians in the near future.
Project 4: [RCN Innovation Project Involving Public-Private Collaboration] Echocardiography Automated diagnostic Interpretation – EchoAI (2020 – 2025)	Project owner	GE Vingmed Ultrasound
	Total budget and share allocated to research group	9.3 MNOK, DSB share 2.9 MNOK
	Objectives and outcomes	Echo AI https://prosjektbanken.forskningsradet.no/project/FORISS/313756 will utilize artificial intelligence to provide workflow improvements by seamlessly integrating image acquisition, analysis and reporting. It will maximize consistency, accuracy, and completeness in accordance with established clinical guidelines. This will be done by developing fully automatic measurements and interpretation of cardiac images originating from an ultrasound scanner. The automated analysis will, in combination with established clinical guidelines, lead to a set of clinical findings. The new product offering will allow for a new and more efficient workflow, where the physician starts with a pre-populated report and can drill down from the high-level findings to individual measurements and images that the findings are based on.

Project 5: [RCN FRIPRO] Airborne Inversion of Rayleigh waves (Funded in 2022 for the 2022-2026 period. However – as all FRIPRO funded projects in this call – the startup was delayed to July 2023 due to RCN economic circumstances)	Project owner	NORSAR, a Norwegian research institute at Kjeller outside of Oslo
	Total budget and share allocated to research group	8 MNOK total, DSB share 0.5 MNOK
	Objectives and outcomes	This RCN FRIPRO ground-breaking research programme project, Airborne Inversion of Rayleigh waves (AIR) https://www.norsar.no/projects/air/, is about using acoustic recordings to probe the interior of Venus. AIR will build numerical models to detect and retrieve Venus interior structure from the sound signature of seismic events on the planet collected by balloon platforms. The research pushes the envelope of balloon technologies for the detection and analysis of natural and anthropogenic events on the Earth and beyond. Project partners: NORSAR; Swedish Institute for Space Physics – IRF (SE); NASA Jet Propulsion Laboratory (associated partner, US); California Institute of Technology – CalTech (US);
Project 6: [RCN IKTPLUSS] Smart AUVs for detection and quantification of greenhouse gas seepage in the oceans (2022 – 2026)	Project owner	NGI (Norwegian Geotechnical Institute)
	Total budget and share allocated to research group	15 MNOK total, DSB share 4.1 MNOK
	Objectives and outcomes	The SmartAUVs project (https://www.mn.uio.no/ifi/english/research/projects/smartauv) objective is to enable more efficient monitoring of greenhouse gas seepage in the oceans through enhanced AUV autonomy. The project will contribute to significant technological advancements related to AUV decision autonomy. It will enable reliable and affordable solutions for marine monitoring of greenhouse gas emissions. Cost-effective marine monitoring will help ensure sustainable and affordable management of marine resources, safe and publicly accepted CO2 storage, and better control over marine greenhouse gas seepage. Research partners: NGI (Norwegian Geotechnical Institute), The Institute of Marine Research (IMR), The Norwegian Defence Research Establishment (FFI), Plymouth Marine Laboratories (PML), The Centre for Deep Sea Research, University of Bergen (UiB), The

		University of Oslo (UiO). Industry partners: Eelume, Kongsberg Maritime (KM), Equinor, Shell, Total Energies
Project 7: [EU] Force: Imaging the Force of Cancer (2016 – 2021)	Project owner	King's College London, UK
	Total budget and share allocated to research group	7.4 MEUR total, DSB share 4.2 MNOK
	Objectives and outcomes	Recent evidence suggests that aggressive metastatic cells exert forces on their surroundings, which could serve as an indicator of metastatic potential. Additionally, many solid tumors have elevated interstitial fluid pressure (IFP), which hinders the efficacy of treatment. To address this issue, the EU-funded FORCE project aims to develop a non-invasive imaging technique to directly visualise these forces in vivo. The proposed magnetic resonance force (MRF) imaging method will measure and analyze the deformation state and biomechanical properties of the tumor and neighboring tissue. The project will also determine if MRF data can predict metastatic spread, measure IFP in patients, and assess the feasibility of utilizing shear forces to modulate the force environment of cancer cells. Project webpage: https://www.mn.uio.no/ifi/english/research/projects/force/
Project 8: [UiO Matnat Faculty] MEDIMA – Multimodal medical imaging and image analysis (2015 – 2020)	Project owner	DSB
	Total budget and share allocated to research group	7.2 MNOK DSB share
	Objectives and outcomes	MEDIMA (https://www.mn.uio.no/ifi/english/research/groups/medima) was a strategic research initiative funded by the Faculty of Mathematics and Natural Sciences. MEDIMA focused on the development of new and improved techniques for medical image formation and analysis. The MEDIMA initiative is cross-disciplinary, spanning from new electromagnetic (radar) imaging technology, through signal processing and image analysis all the way to clinical evaluation of medical imaging solutions. The MEDIMA project laid the foundation for the successful application of the DoMore! Project.

Project 9: [UiO Matnat Faculty] INIUS – Intelligent image-guided surgery (2018 – 2022)	Project owner	DSB
	Total budget and share allocated to research group	4.8 MNOK DSB share
	Objectives and outcomes	The Innovation Cluster INIUS (https://www.mn.uio.no/ifi/english/research/projects/inius/) aimed to make a significant contribution to developing tomorrow's solutions for intelligent image-guided treatment. These solutions should help to enable minimally invasive treatment of the heart to be carried out by interdisciplinary teams in an efficient and safe manner. This was made possible by developing solutions that provided visual guidance during the procedure. This guidance combined multiple image sources and INTEGRAT both domain knowledge and artificial intelligence. INIUS had the following sub-goals: • Identify anatomical landmarks and structures in real-time 3D data. • Identify and extract clinically relevant sections in real-time. • Fuse 3D ultrasound with CT, MRI, and X-ray in an intuitive manner. • Combine robotics with ultrasound to automatically control ultrasound probes. • Visualize fused images using holographic/Augmented Reality display solutions.
Project 10: [RCN Innovation Projects for the Industrial Sector] INCUS – The Intelligent Cardiovascular Ultrasound Scanner (2016 – 2019)	Project owner	GE Vingmed Ultrasound
	Total budget and share allocated to research group	14.3 MNOK total, DSB share 3.4 MNOK
	Objectives and outcomes	The INCUS project (https://www.mn.uio.no/ifi/forskning/prosjekter/intelligent-cardiovascular-ultrasound-scanner) has been concerned with improvements of ultrasound examinations of the heart through automating workflow, image adjustments, measurements and to some extent interpretation of images by use of artificial intelligence. Throughout the project we have in most cases followed the following approach: • Collection of ultrasound images • Manuel classification/measurement of the ultrasound images • Training of a deep neural network • Validation of the results

		The INCUS project has established a database containing anonymized cardiac image sequences from different patient populations, with different ethnic background, different gender, and age. The image sequences originate from hospitals in Europe and Asia. In the project, scientists, PhD students, post-doc fellows and developers have worked together to bring to reality different applications of artificial intelligence in ultrasound: • Cardiac View recognition • Doppler Spectrum recognition • Auto Frequency The INCUS project has also made noteworthy progress in recognizing structures and landmarks in ultrasound images. In addition, we have developed models to grade image quality and mitral regurgitation automatically using AI.
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Table 5. Research group's contribution to publications.

Please select 5-15 publications from the last 5 years (2018-2022) with emphasis on recent publications where group members have a significant role.

Publication 1: "Designing deep learning studies in cancer diagnostics" <i>Nature Reviews Cancer</i> 21, no 3 (2021): 199-211 https://doi.org/10.1038/s41568-020-00327-9	Authors	Andreas Kleppe, Ole-Johan Skrede, Sepp De Raedt, Knut Liestøl, David J Kerr, Håvard E Danielsen
	Short description	If artificial intelligence-based technology for cancer diagnostics exists, why is it still not in use? How can new knowledge in deep learning and artificial intelligence in diagnostics benefit cancer patients in the fastest and safest way? The project tackled several of the reasons behind the moderate progress and description for remedies designed to facilitate the transition from research to clinical use.
	Research group's contribution	OJ-S and SDR held full positions in DSB during part of the time of the work AK and HED hold adjoint positions in the group. HED and DJK initiated the project. All authors researched data for the article AK, O-JS and KL evaluated the recent, presumably influential, deep learning studies in cancer diagnostics SDR executed the training, tuning and evaluation of Inception-v3 systems. AK drafted the manuscript, and all authors contributed to reviewing and editing the manuscript.
Publication 2:	Authors	Ole-Johan Skrede, Sepp De Raedt[†], Andreas Kleppe, Tarjei S Hveem, Knut Liestøl, John Maddison, Hanne A Askautrud, Manohar Pradhan, John Arne Nesheim, Fritz Albregtsen, Inger Nina Farstad, Enric

"Deep learning for prediction of colorectal cancer outcome: a discovery and validation study" <i>The Lancet</i> 395, no 10221 (2020): 350-360 https://doi.org/10.1016/S0140-6736(19)32998-8		Domingo, David N Church, Arild Nesbakken, Neil A Shepherd, Ian Tomlinson, Rachel Kerr, Marco Novelli, David J Kerr, Håvard E Danielsen . († Contributed equally)
	Short description	The aim of the study was to develop a biomarker of patient outcome after primary colorectal cancer resection by directly analyzing scanned conventional haematoxylin and eosin-stained sections using deep learning. More than 12 000 000 image tiles from patients with a distinctly good or poor disease outcome were used to train a total of ten convolutional neural networks. A prognostic biomarker integrating the ten networks was determined using patients with a non-distinct outcome. A clinically useful prognostic marker was developed using deep learning allied to digital scanning of conventional haematoxylin and eosin-stained tumor tissue sections. The assay has been extensively evaluated in large, independent patient populations, correlates with and outperforms established molecular and morphological prognostic markers, and gives consistent results across tumor and nodal stage.
	Research group's contribution	O-JS, SDR, FA held full positions in DSB AK and HED holds adjoint positions in the DSB group. O-JS, SDR, AK, TSH, KL, FA, DJK, and HED designed the study. HAA, JAN, AN, NAS, IT, RK, MN, and DJK collected the samples and acquired the image data. MP, INF, ED, DNC, AN, NAS, IT, RK, MN, and DJK provided the clinical and pathological data and interpretations O-JS, SDR, and JM performed the machine learning. AK did the statistical analyses O-JS, SDR, AK, TSH, KL, DJK, and HED interpreted the data and analyses. All authors vouch for the data, analyses, and interpretations. O-JS, SDR, AK, TSH, KL, DJK, and HED wrote the first draft of the manuscript, and all authors reviewed, contributed to, and approved the manuscript.
Publication 3: "Convolutional neural networks for automated seismic interpretation" <i>The Leading Edge</i> 37, no 7 (2018): 529-537 https://doi.org/10.1190/tle37070529.1	Authors	Anders U Waldeland, Are Charles Jensen, Leiv-J Gelius, and Anne H Schistad Solberg
	Short description	The paper discusses the use of convolutional neural networks (CNNs) for automated seismic interpretation. The input to the network is the raw image or seismic amplitudes, removing the need for feature/attribute engineering. During the training phase, the filter coefficients are found by iterative optimization. The network thereby learns how to compute good attributes to solve the given classification task. However, CNNs require large amounts of training data and must be carefully designed and trained to perform well. We investigate the intuition behind this method and discuss considerations that must be made in order to make the method reliable. In particular, we discuss how deep learning can be used for automated seismic interpretation. As an example, we show how a CNN can be used for automatic interpretation of salt bodies.

	Research group's contribution	This work was part of the PhD of AUW. The other authors were his PhD advisors. Hence, three out of four authors are from DSB.
Publication 4: "Pruning by explaining: A novel criterion for deep neural network pruning" <i>Pattern Recognition</i> 115 (2021): 107899 https://doi.org/10.1016/j.patcog.2021.107899	Authors	Seul-Ki Yeom, Philipp Seegerer, Sebastian Lapuschkin, Alexander Binder , Simon Wiedemann, Klaus-Robert Müller, and Wojciech Samek
	Short description	A novel criterion to efficiently prune convolutional neural networks inspired by explaining nonlinear classification decisions in terms of input variables is introduced. The method is inspired by neural network interpretability: Layer-wise Relevance Propagation. This is the first report to link the two disconnected lines of interpretability and model compression research. The method is tested on two popular convolutional neural network families and a broad range of benchmark datasets under two different scenarios.
	Research group's contribution	This work was completed while AB was Associate Professor in the DSB research group.
Publication 5: "The generalized contrast-to-noise ratio: A formal definition for lesion detectability" <i>IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control</i> 67, no 4 (2019): 745-759 https://doi.org/10.1109/TUFFC.2019.2956855	Authors	Alfonso Rodriguez-Molares, Ole Marius Hoel Rindal , Jan D'hooge, Svein-Erik Måsøy, Andreas Austeng , Muyinatu A Lediju Bell, and Hans Torp
	Short description	In this paper we generalize the definition of contrast-to-noise ratio (CNR) based on the overlap area between two probability density functions. This generalized CNR (gCNR) is robust against dynamic range alterations; it can be applied to all kind of images, units, or scales; it provides a quantitative measure for contrast; and it has a simple statistical interpretation, i.e., the success rate that can be expected from an ideal observer at the task of separating pixels. We test gCNR on several state-of-the-art imaging algorithms and, in addition, on a trivial compression of the dynamic range. We observe that the traditional CNR varies greatly between the state-of-the-art methods, with improvements larger than 100%. We observe that trivial compression leads to a CNR improvement of over 200%. The proposed index, however, yields the same value for compressed and uncompressed images. This new metric fixes a methodological flaw in the way we study contrast and allows us to assess the relevance of new imaging algorithms.
	Research group's contribution	This is collaborative work done in the team that at the time took part in developing the USTB toolbox . AR-M and OMHR shared responsibility for implementing, analyzing, and writing the first draft of the paper. JD, S-EM, AA, MALB, and HT supervised the work, were discussion partners, and took part in finalizing the paper.

Publication 6: "Morphological and molecular breast cancer profiling through explainable machine learning" <i>Nature Machine Intelligence</i> 3, no 4 (2021): 355-366 https://doi.org/10.1038/s42256-021-00303-4	Authors	Alexander Binder , Michael Bockmayr, Miriam Hägele, Stephan Wienert, Daniel Heim, Katharina Hellweg, Masaru Ishii, Albrecht Stenzinger, Andreas Hocke, Carsten Denkert, Klaus-Robert Müller, Frederick Klauschen.
	Short description	The paper presents an explainable machine-learning approach for the integrated profiling of morphological, molecular, and clinical features from breast cancer histology. First, our approach allows for the robust detection of cancer cells and tumour-infiltrating lymphocytes in histological images, providing precise heatmap visualizations explaining the classifier decisions. Second, molecular features, including DNA methylation, gene expression, copy number variations, somatic mutations and proteins are predicted from histology. Molecular predictions reach balanced accuracies up to 78%, whereas accuracies of over 95% can be achieved for subgroups of patients. Finally, our explainable AI approach allows assessment of the link between morphological and molecular cancer properties. The resulting computational multiplex-histology analysis can help promote basic cancer research and precision medicine through an integrated diagnostic scoring of histological, clinical, and molecular features.
	Research group's contribution	This work was completed while AB was Associate Professor in the DSB research group. AB, MB, MH, K-RM and FK conceptualized the project. AB, MB, KH, MH, SW, DH, K-RM and FK were responsible for the methodology. AB, MB, MH, SW, DH, K-RM and FK developed the software. AB, MB, MH, K-RM and FK were responsible for validation. AB, MB, MH, and FK conducted the formal analysis. AB, MB, MH, CD, K-RM and FK performed investigation. AB, MI, CD, K-RM and FK were responsible for resources. Data curation was completed by AB, MB, DH, and FK; AB, MB, K-RM and FK wrote the first draft, which was reviewed and edited by AB, MB, MH, SW, DH, KH, DT, MI, AS, AH, CD, K-RM and FK. Visualization was performed by AB, MB, MH, and FK; K-RM and FK supervised the project. Funding was secured by AB, MI, K-RM and FK.
Publication 7: "The effect of dynamic range alterations in the estimation of contrast" <i>IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control</i> 66, no 7 (2019): 1198-1208	Authors	Ole Marius Hoel Rindal, Andreas Austeng , Ali Fatemi, and Alfonso Rodriguez-Molares
	Short description	In this paper we form the hypothesis that contrast improvements from adaptive beamformers can, partly, be due to dynamic range alterations (DRAs). The work confirms this hypothesis. We show evidence on the influence of DRA on the estimation of the contrast ratio (CR) and the contrast-to-noise ratio (CNR) and on the fact that several methods in the state of the art do alter the DR. To study this phenomenon, we propose a DR test (DRT) to estimate the degree of DRA and we apply it to seven beamforming methods. We show that CR improvements correlate with DRT with $R^2\text{-adj} = 0.88$ in simulated data and $R^2\text{-adj} = 0.98$ in experiments. We also show that DRA may lead to

https://doi.org/10.1109/TUFFC.2019.2911267		increased CNR values, under some circumstances. These results suggest that claims on lesion detectability, based on CR and CNR values, should be revised.
	Research group's contribution	OMHR, AA, and AR-M designed the study OMHR implemented all algorithms, made simulations, performed all analysis, and wrote the first draft of the paper. AF and AR-M provided experimental data. All authors took part in finalizing the paper.
Publication 8: "IMS observations of infrasound and acoustic-gravity waves produced by the January 2022 volcanic eruption of Hunga, Tonga: A global analysis" <i>Earth and Planetary Science Letters</i> 591 (2022): 117639 https://doi.org/10.1016/j.epsl.2022.117639	Authors	Julien Vergoz, Patrick Hupe, Constantino Listowski, Alexis Le Pichon, M A Garcés, Emanuele Marchetti, Philippe Labazuy, Lars Ceranna, Christoph Pilger, Peter Gaebler, Sven Peter Näsholm , Quentin Brissaud, Pedro Poli, Nicolas Shapiro, Rodrigo De Negri, Pierrick Mialle.
	Short description	This already highly cited paper represents a new acoustics-related research branch brought to DSB through the newly recruited Assoc. Prof. SPN: Low-frequency inaudible sound – infrasound – can propagate for thousands of kilometers in the Earth's atmosphere and represent an untapped potential for probing the winds of the upper atmosphere This paper looks at the global signature of the exceptionally energetic volcano eruption in early 2022 in Hunga, Tonga (Oceania). Infrasound waves from this extraordinary event were detected after seven complete Earth circumnavigations, more than 13 days after the blast.
	Research group's contribution	Conceptualization: JV, ALP; Formal analysis: JV, PH, CL, MAG, LC, CP, SPN , QB, PP, RN, PM; Investigation: JV, PH, CL, ALP, MAG, EM, PL, LC, CP, SPN , QB, PP, NS, RN, PM; Methodology: JV, PH, CL, MAG, LC; Validation: JV, PH, CL, MAG, CP; Visualization: PG, JV, PH, CL, SPN , LC; Writing – original draft: JV, PH, CL, ALP, MAG, EM, PL, CP, LC, SPN , QB, PP, RN; Writing – review & editing: all authors
Publication 9: "Chromatin organisation and cancer prognosis: a pan-cancer study" <i>The Lancet Oncology</i> 19, no 3 (2018): 356-369 https://doi.org/10.1016/S1470-2045(17)30899-9	Authors	Andreas Kleppe, Fritz Albrechtsen , Ljiljana Vlatkovic, Manohar Pradhan, Birgitte Nielsen, Tarjei S Hveem, Hanne A Askautrud, Gunnar B Kristensen, Arild Nesbakken, Jone Trovik, Håkon Wæhre, Ian Tomlinson, Neil A Shepherd, Marco Novelli, David J Kerr, Håvard E Danielsen
	Short description	The study evaluated a novel biomarker, Nucleotyping, for automatic detection of chromatin organization variation, which often leads to cancer. Machine learning algorithms were used in the study to analyze DNA-stained images of tumor cell nuclei from different patients. The novel biomarker has demonstrated consistent prognostic prediction in different biological and technical situations. The study found that patients with chromatin heterogeneous tumors had worse cancer-specific survival than those with chromatin homogeneous tumors. Therefore, this research opens the opportunity that Nucleotyping could be used in clinical practice, objectively aiding decision-making across various clinical

		settings. This could specifically help identify high-risk stage II colorectal cancer patients who might benefit significantly from adjuvant chemotherapy. Further clinical trials are, however, needed to evaluate the survival benefit and cost-effectiveness of Nucleotyping in guiding treatment decisions in other different clinical settings.
	Research group's contribution	AK, FA, DJK, and HED were involved in study design. HAA, GBK, AN, JT, HW, NAS, and DJK collected the data LV, MP, and NAS did the pathological evaluations. AK, FA, BN, TSH, IT, MN, DJK, and HED analyzed and interpreted the data. AK wrote the first draft, and all authors reviewed, contributed to, and approved the manuscript.
Publication 10: "Towards a consensus on rheological models for elastography in soft tissues" <i>Physics in Medicine & Biology</i> 64, no 21 (2019): 215012 https://doi.org/10.1088/1361-6560/ab453d	Authors	Kevin J Parker, Thomas Szabo, and Sverre Holm
	Short description	Together with the book <i>Waves with Power-Law Attenuation</i> , this paper represents a productive line of DSB research headed by Prof. Holm. In a significant body of publications, DSB researchers have worked on deriving physically and mathematically consistent wave modelling approaches for complex media with power-law attenuation. A key application is medical ultrasound and elastography, where the frequency-dependent attenuation follows a power-law with an exponent close to one. It turns out that conventional modelling of this attenuation law implicitly can break the fundamental property of causality of physical systems.
	Research group's contribution	SH and the two other authors – who have previously developed different approaches in the modelling of power-law attenuation in acoustics and elastography – together sought to provide clarity on the differences and implications of commonly used rheological models elastography. Ultimately, the goal is to achieve consensus among various sub-fields in acoustics, biomechanics, and elastography that share an interest in comparing tissue measurements.

Table 6. The research groups monographs/scientific books.

1	Sverre Holm – Waves with Power-Law Attenuation https://doi.org/10.1007/978-3-030-14927-7
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2.2 Research group's societal contribution

Describe the societal impact of the group's research. Consider contribution to education, economic, societal, and cultural development in Norway and internationally.

The DSB research projects have resulted in several patented methods and systems to improve ultrasound imaging, adaptive beamforming, and histological image analysis. The Ultrasound Toolbox (USTB) facilitates research collaboration and knowledge sharing in the domain of ultrasound image reconstruction, being applied both in academic research and in commercial product development worldwide. Ultimately, DSB research has driven advancements and innovation in medical imaging, leading to enhanced patient diagnosis.

In addition to our PhD research fellows who are employed at IFI and listed in Section 1.1, DSB also contributes to enhancing the research expertise and activity in industry through the RCN industrial PhD scheme. In the period 2018–2022, DSB has hosted and supervised three PhD research fellows in collaborations with the private companies Kongsberg Maritime, Petroleum Geo-Services (PGS), and Equanostic AS. Similarly, three PhD research fellows employed at GE Vingmed Ultrasound and funded through the EU Horizon 2020 Innovative Training Network (ITN) projects [MARie Curie Intelligent UltraSound](#) (MARCIUS) and [Personalised In-Silico Cardiology](#) were hosted by DSB. These five students are enrolled in the same UiO PhD programme as our IFI employed PhD research fellows.

Another example of societal development and global security contributions is in array signal processing research generating algorithms that facilitate the global monitoring of the nuclear test-ban-treaty that bans nuclear explosions. See Table 7 for concrete examples of DSB publications, products, and software related to these societal contributions.

Through the DoMore! project, the [DoMore Diagnostics AS](#) company was established and is operable since 2021. Their mission is to transform cancer diagnostics with artificial intelligence to improve patient care and to make drug development more effective.

Table 7. The research group's societal contribution, including user-oriented publications, products (including patents, software, or process innovations).

No	Name of publication/product	Date of publication/product	Link to the document
1	Erik Normann Steen, Sten Roar Snare , and Hani Nozari Mirarkolaei "Method and system for enhanced frame rate upconversion in ultrasound imaging" US Patent 9,384,568,	Issued 5 July 2016	https://patents.google.com/patent/US9384568B2/en
2	Ole Marius Hoel Rindal , Andreas Austeng , Alfonso Rodriguez-Molares "Method and apparatus for adaptive beamforming" Patent application US2022155439 (A1) / WO2021009495 (A1)	Published 18 May 2022	https://patentscope.wipo.int/search/en/detail.jsf?docId=WO2021009495
3	Sverre Holm "Ultrasound zone location system with high capacity" Patent US8779895B2	Granted 14 July 2014	https://patents.google.com/patent/US8779895B2/en
4	Ole Johan Skrede , Tarjei Sveinsgjerd Hveem, John Robert Maddison, Havard Emil Greger Danielsen , Knut Liestøl "Histological image analysis" Patent application EP3711018A1. This is also related to the DoMore Diagnostics company establishment, as further discussed in the Section 2.2 textbox.	Published 23 September 2020	https://worldwide.espacenet.com/patent/search/family/060805742/publication/EP3711018A1?q=pn%3DEP3711018A1%3F
5	The Ultrasound Toolbox (USTB) This is a processing framework for ultrasound signals USTB aims to facilitate the comparison of imaging techniques and the dissemination of research results Since its release in 2017, it has been further developed and enhanced by researchers in ultrasound laboratories all over the world, both in industry and academia	Paper published in 2017, together with the first release of the open software USTB is continuously evolving thanks to contributions from all over the world	Open software website: http://www.ustb.no/ and repository: https://bitbucket.org/ustb/ustb/src/master Scientific paper: https://doi.org/10.1109/ULTSYM2017.8092389
6	Three different Disclosures of Invention (DOFI) submitted within the CIUS centre with DSB group members as authors	2015–2022	https://www.ntnu.edu/cius
7	Tormod Kværna, Steven J Gibbons, Sven Peter Näsholm "CTBT seismic monitoring using coherent and incoherent array processing" <i>Journal of Seismology</i> 25, no 5 (2021): 1189-1207	Paper in 2021. This tackles seismological signal processing for operational monitoring of the Comprehensive Nuclear-Test-Ban Treaty (CTBT) which has the important societal role of prohibiting nuclear weapon test explosions and any other nuclear explosion	The Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO): https://www.ctbto.org/

3 Challenges and opportunities

Information about the strengths and weaknesses of the research group is obtained through the questions above. In this chapter, please reflect on what might be the challenges and opportunities for developing and strengthening the research and the position of the group.

The DSB publication record is solid, and it is paramount to maintain both quality and quantity of peer-review publication to remain attractive for research collaboration and project funding.

The DSB research group landscape involves both opportunities and challenges. We are proud of our strong partnerships and contributions to prestigious projects like CIUS and VI-SFI, the high demand for our graduates in industry and academia, as well as our fundamental expertise in machine learning, computer vision, acoustical imaging, and signal processing. A strength is the relevance of our research to the industry and the health sectors, which provides unique opportunities for both educational and societal impact.

There is an absence of a dedicated IFI BSc programme to educate a large enough and diverse enough number of students with the appropriate combination of skills needed to tackle modern machine-learning and signal processing problems. This is to some extent mitigated by the fact that BSc programmes managed by other departments such as the Department of Mathematics and the Department of Physics, are educating candidates with profiles that fit DSB. To remedy this lack of students, the DSB group together with two other research groups in the section – the Language Technology Group and the Scientific Computing and Machine Learning group – are in the process of establishing a new BSc programme in machine learning at the department. Moreover, the increasing need for computational infrastructure for machine learning might hinder us from reaching our full research output potential.

The breadth of scientific domain expertise within DSB gives flexibility and versatility. However, this comes with the risk of the group becoming too fragmented and lacking enough redundancy among the permanent faculty staff. The generational shift in permanent staff brings fresh perspectives, but also concerns in terms of a prospective lack of continuity. We feel there is an untapped potential in exploiting the full chain of expertise that DSB covers, for example in medical ultrasound imaging where we have produced top research on several of the individual components that build the signal processing pipeline from raw sensor data all the way to annotated and machine learning enhanced images used in medical diagnosis. Here, a consolidated approach might provide new research breakthroughs to solidify DSB as a research group in the international forefront.

Our collaborations and the high industry and research demand for machine learning and image analysis open doors to growth. However, there is a competitive landscape for talent against other academic labs and industry, and we fear it might become increasingly difficult to recruit the best students to our PhD positions.