2021 ANNUAL REPORT

CIUS

Centre for Innovative Ultrasound Solutions

sfi Centre for Research-based Innovation

cius

NTNU Norwegian University of Science and Technology

Academic Partners

NTNU Norwegian University of Science and Technology

SINTEF

UiO University of Oslo

USN University of South-Eastern Norway

Industry Partners

equinor

Archer

AUROTECH ULTRASOUND

InPhase Solutions

GE Vingmed Ultrasound

GE Healthcare Women's Health Ultrasound

MEDISTIM

KONGSBERG

NDT GLOBAL

Sensorlink

EXACT THERAPEUTICS

Re{Lab}

xfab

Health Sector Partners

HELSE MIDT-NORGE

HELSE NORD-TRØNDELAG

ST. OLAVS HOSPITAL TRONDHEIM UNIVERSITY HOSPITAL

SØRLANDET SYKEHUS

Levanger kommune

VERDAL KOMMUNE

Associated Partner

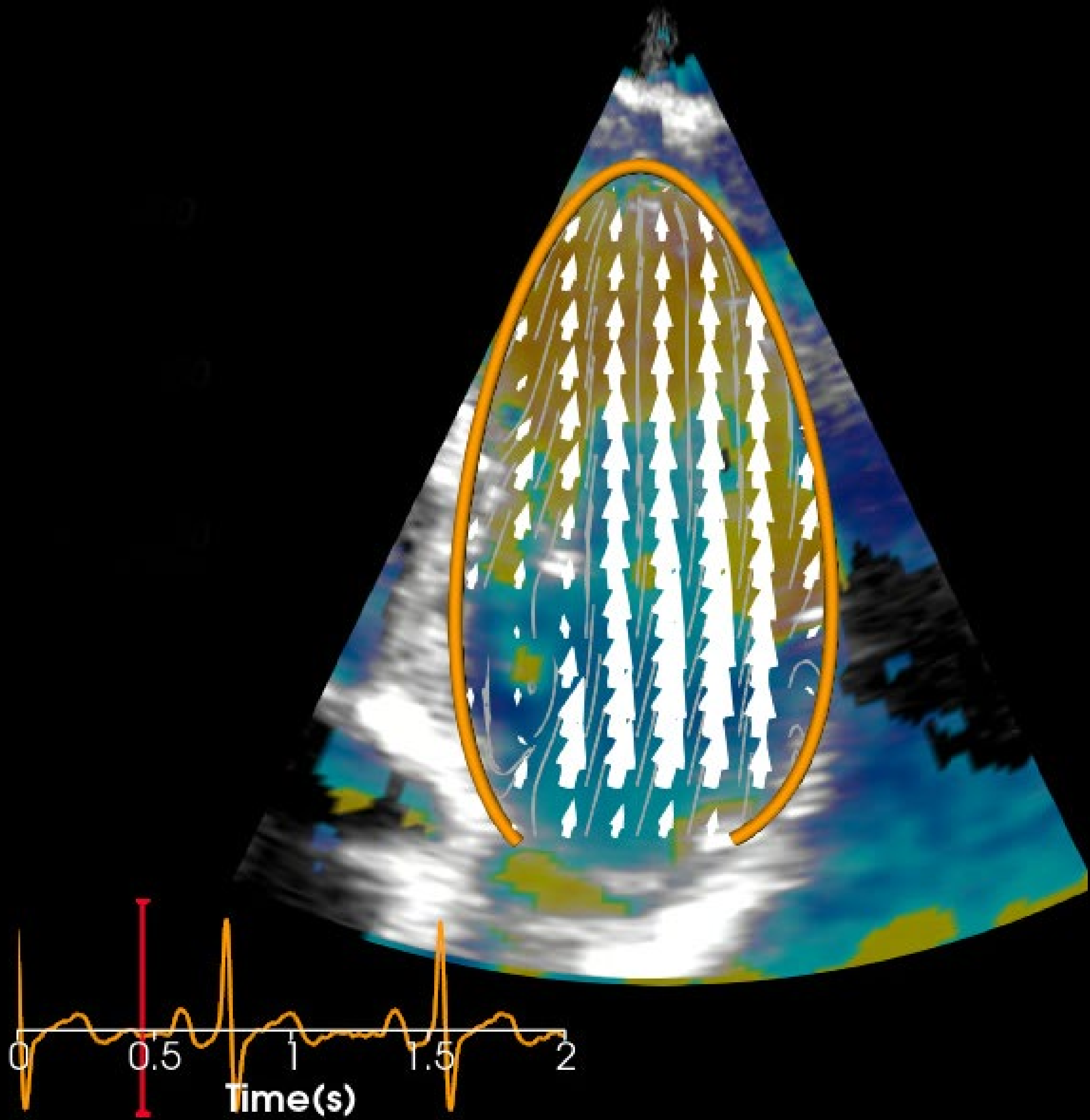
FFI Forsvarets forskningsinstitutt
Norwegian Defence Research Establishment

Host

NTNU | Faculty of Medicine and Health Sciences
Department of Circulation and Medical Imaging

Contents

Early rapid filling (E-wave): Rapid inflow from the atrium to the ventricle, and subsequent reversal of flow due to basal movement with vortex development on both sides of the mitral valve. Image: Annichen Søyland Daae/NTNU.



Asta Håberg
Centre Director

Dear CIUS family

"I would like to thank all those contributing to SFI CIUS' success during 2021 as I am leaving the leadership to Dr. Svein-Erik Måsøy from January 2022."

In December 2021 we arranged the first CIUS in-person conference since 2019. It felt great to meet again in real life. A brief overview of the conference topics can be found on the conference website (www.ntnu.edu/cius/cius-fall-conference-2021). We are hopeful the positive trend continues allowing for the CIUS spring-conference to take place in Årsgårdstrand/Horten as planned in May 2022.

CIUS is in its 6th year and the activity is still expanding. We got a new industry partner, GE Healthcare Women's Health Ultrasound (GEWHUS), opening for extending the clinical activity into the realm of gynaecology and obstetrics. The new funding from GEWHUS enables hiring of senior researchers as well as a new PhD. CIUS also diversified in collaboration with already existing partners in 2021 by starting up a novel ultrasound imaging solutions project for fish health in collaboration with InPhase Solutions.

Despite Covid, CIUS researchers published several scientific papers last year (p. 70), including one in the prestigious Journal of American College of Cardiology. Researchers at all levels participated in virtual conferences, but the lack of physical meetings and chance encounters with fellow researchers is severely limiting the experience, especially for the new PhD candidates. CIUS has onboarded a whole new generation of PhD candidates during the pandemic, and their introduction into the scientific community has unfortunately been affected by Covid and the restrictions implemented. Luckily, all have shown significant resourcefulness and resilience, and projects are progressing albeit some slower while others detour from the original plan. The overview of the PhDs and master's degrees (p. 75) obtained, show that CIUS has adapted and been able to deliver also in the second year of the pandemic. CIUS PhD and postdocs are sought after and are hired by relevant industry often before graduation. This is a clear indication of the relevance of the scientific training and the advantage of being part of a large consortium with its networking possibilities

2021 was an excellent year for innovation in CIUS with 7 DOFIs, five signed licence agreements and the start of four other licence agreement negotiations. The collaborations between academic researchers and CIUS' industry and user partners have deepened and matured since the start of the project. This is clearly reflected in the increasing in-kind contributions (p. 69) and number of licence agreements. We see that technological innovations and developments in one area are implemented in other fields and further developed, demonstrating the generic nature of the research in CIUS. These deliveries are proof that the concepts and research methodology outlined in the application are working in real life with positive synergies across the consortium.

I would like to thank all those contributing to SFI CIUS success during 2021 as I am leaving the leadership to Dr. Svein-Erik Måsøy from January 2022. He will steer CIUS to the new, updated end date, 30 April, 2024, due to the Covid pandemic.

Brita Pukstad
Vice Dean

Greetings from the Vice Dean

"CIUS has managed to maintain its scientific and innovative activity throughout the pandemic, creating great value in working with ultrasound technologies across different academic fields in collaboration with industrial partners."

NTNU's strategy is *Knowledge for a better world*, and our strength lies in our competence in science and technology. Great results are achieved through interdisciplinary and collaborative work in centres for research-based innovation, such as CIUS. The Faculty of Medicine and Health Sciences (MH) at NTNU is proud to be the host for CIUS.

Health for a better world is the strategy of the MH faculty. Our aim is to develop knowledge, skills and solutions that contribute to good health through research, education, innovation, and dissemination. With the Covid-19 pandemic from 2020 continuing through all of 2021 we have seen more than ever how important it is to have a global perspective and awareness in addition to our regional and national responsibilities. Our students are our future and our popular study programmes continue to have a high number of applicants and good evaluations. During the crisis our researchers have continued to publish their work, PhD defences have been held on digital platforms, and new ideas have been brought forward to be patented and commercialised. CIUS has contributed highly here, and we are excited to be a part of it.

The strategy *Health for a better world* is indeed ambitious. We have committed ourselves to stay true to the UN Sustainable Development Goals, and in 2021 we started a process to move towards implementing these goals in all our activities. We need to enable a fairer distribution of knowledge and resources, fight inequality and strengthen our commitment to address the challenges in global health and climate change. The pandemic has required us to travel less, and with fewer flights and a reduced carbon footprint we have started to contribute to these global challenges. We have learned that it is possible to collaborate through digital platforms. Although virtual networking cannot fully replace the opportunities that arise in face-to-face meetings, we will continue to travel less in the future and take steps to reduce our effect on the climate.

An increased focus on innovation and collaboration between academia, industry and the public sectors is central for the MH Faculty. We are pursuing these goals at every level in the organisation and have high expectations of our student-lead health innovation lab, DRIV NTNU. DRIV is established to facilitate innovative activity for our future health workers, academic colleagues, and collaborators, and is open to all students interested in health innovation. We continue to support and contribute to an increasing demand for innovative skills and knowledge by supporting the School of Health Innovation for PhD students, clinicians, postdoctoral fellows and supervisors. We are excited about the opportunities our new membership in EIT Health will bring in the coming years.

The centres for research-based innovation, such as CIUS, embody the culture NTNU aspires to in its strategy. CIUS has managed to maintain its scientific and innovative activity throughout the pandemic, creating great value in working with ultrasound technologies across different academic fields in collaboration with industrial partners.

We look forward to continuing our engaging collaboration with CIUS in 2022!

Eva Nilssen
Board Leader

Greetings from the CIUS Board

"All the knowhow developed in CIUS now has the potential to not only improve the quality of life for patients by better medical diagnostics, but also addresses some of the environmental challenges we face with ageing oil & gas equipment, ocean pollution and the need for new and greener energy sources."

Much has happened since we started in 2016, exploring the possibility to learn from each other and from the expertise of the different industry partners. We have acted upon this knowledge in research collaborations in these areas as we anticipated when first applying for the grant, especially in Work Package 1 (WP1) Transducer and Electronics, Work package 2 (WP2) Acoustics and Beamforming and more recently, also in Work Package 3 (WP3) Doppler and deformation imaging. In WP3 the researchers are utilising the doppler expertise from medical ultrasound applications at NTNU, applying this to research for Oil & Gas applications.

One promising example of this is the estimation of influx/efflux and flow leakage while drilling boreholes. Leakage of drilling fluid is expensive and in worst case could lead to a blowout, like the Deep Water Horizon event in 2010 in the Mexican Gulf. Doppler methods for early detection of the size of leakages (influx/efflux), like what is done in medical ultrasound for detecting valvular leaks, is showing promising result in estimating the size and geometry of the orifice. Enabling the oil companies to do the necessary pre-cautionary measures to prevent accidents from happening in the oil fields.

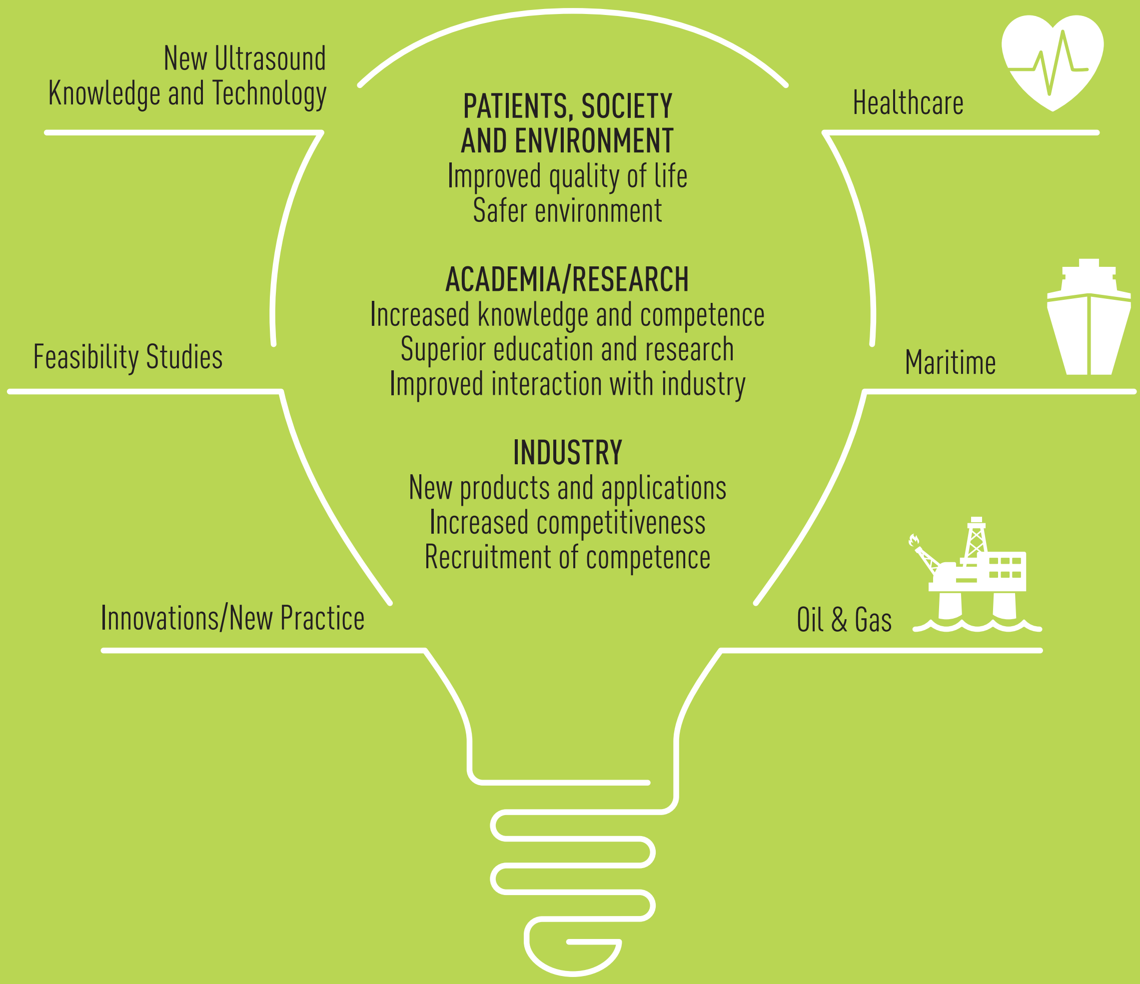
At the start of CIUS, Work Package 4 (WP4) Image processing, analysis, and visualisation, the power of Machine Learning (ML) or Artificial Intelligence (AI) was still uncertain for ultrasound applications. But during the course of the CIUS programme the AI technology has become a vital part of CIUS research, contributing to all fields of use. This is in line with global trends. For medical ultrasound, the technology is now widely used for improved accuracy and faster diagnosis as well as user guidance for the optimal acquisition of images. Many AI algorithms are already implemented and commercialised in GE, and in daily use for better diagnosis all around the globe. The research activities in CIUS are well aligned with the internal research in GE. The engagement and contribution from the medical partners in CIUS, especially from the St. Olavs staff, has been crucial in the selection of research topics, making sure that the technology is applied to real clinical needs and not just research into a fancy new technology. This clinical engagement is of vital importance for successful outcomes.

Manual analysis of oil well logs is a complex and lengthy process, very much dependent on the expertise of the reviewer, much as it is for analysis of medical ultrasound images. Automation of oil well analysis by utilising AI techniques has a great potential for improving accuracy and faster evaluation of oil well logging, supporting the experts and opening up for deeper insights into the even more complex areas of the logs. Similarly for maritime and seabed mapping: The AI technology and the competency gains from research in oil & gas and medical ultrasound, is very useful for analysis of sonar data.

These are some examples of the synergy effects from the CIUS consortium and the potential gains from such large multi-disciplinary research environments. As we now move into our final years of the CIUS project, this is a great foundation for applying for a new SFI. The Research Council of Norway (RCN) has confirmed that we can apply for a new SFI with the same or similar partners as we have today, but with the addition of some new focus areas and some new partners. All the knowhow developed in CIUS now has the potential to not only improve the quality of life for patients by better medical diagnostics, but also addresses some of the environmental challenges we face with ageing oil & gas equipment, ocean pollution and the need for new and greener energy sources. Preparations for a new SFI application is starting in 2022, and I am encouraging all partners to contribute with ideas and input to this work.

CIUS Idea

CIUS delivers novel ultrasound technology solutions for the benefit of the involved partners, new diagnostic tools for the benefit of patients and the healthcare providers, important knowledge disseminated in highly recognised scientific journals, and skilled personnel to further exploit the future potential of ultrasound imaging in Norwegian industries, healthcare and academia.



The CIUS Concept

The Centre for Innovative Ultrasound Solutions (CIUS) combines frontier academic research in ultrasound technology development with innovation in leading Norwegian ultrasound companies working in medical, maritime, and oil & gas application areas.

The core of CIUS' projects revolves around three main topics within the three application areas: Healthcare: Improvement of cardiovascular ultrasound; Maritime: Sonar imaging and fish health; Oil & gas: Monitoring the integrity and safety of wells and pipelines.

The potential impact of CIUS innovations within these areas is described with examples from CIUS' partners:

- Healthcare: Cardiovascular disease is the leading cause of death and morbidity worldwide. Ultrasound is the leading image modality for assessing cardiovascular disease. GE Vingmed Ultrasound is the world leader in cardiovascular ultrasound, and their systems are used to investigate more than 300 000 people on a daily basis.
- Maritime: More than 90% of the global fleet mapping the world's fishing resources, and therefore determining quotas for fishing, use SONARs from Kongsberg Maritime Subsea. Also, 99% of the ocean floor is still unexplored and KM is a world leader in SONARs and AUVs for seabed mapping. Furthermore, Norwegian fish farming has a turnover of more than NOK 65 million annually – CIUS is exploring the use of ultrasound to improve the health of farmed fish/broodfish with InPhase Solutions, AquaGen and Mowi.
- Oil & gas: Equinor is going to plug & abandon (P&A) thousands of wells on the Norwegian Continental Shelf in the next 20 years. Assessing the integrity and safety of operating wells and verifying that the downhole well barriers are fit for permanent P&A, both rely heavily on sonic and ultrasonic borehole logging and imaging. Advances within these domains enable cost-efficient abandonment methods and ensure that the plugged wells are environmentally safe for generations to come.

Ultrasound technology as used in the three sectors has a tremendous unexplored potential for meeting future challenges. In CIUS, industry, academia, public institutions, and private research foundations join forces and explore synergies across disciplines, leveraging next-generation ultrasound technology for a better world. Key ultrasound research tasks are within transducer design, acoustics and image formation, Doppler and deformation imaging, as well as image analysis and visualisation. By applying these technologies to specific innovation goals within each sector, significant business opportunities in the international market can be achieved. CIUS will by unique competence and innovations, secure long-term competitive advantage within areas where Norway is internationally recognised for excellent research, innovation, and product deliveries.

CIUS is hosted by the Department of Circulation and Medical Imaging, Faculty of Medicine and Health Sciences at the Norwegian University of Science and Technology (NTNU), Norway's largest university. The ultrasound group at NTNU is known for its expertise within ultrasound research and innovation in healthcare through 40 years. Expertise and research facilities are joined in a virtual laboratory organisation including selected Norwegian academic institutions and important cornerstone enterprises as well as several small-to-medium enterprises (SMEs) in Norway. CIUS encompasses 4 research partners, 13 industrial/corporate partners, and 6 healthcare user partners.

Research Methodology

The research methodology in CIUS is an iterative process between curiosity-driven technological development and user-involved feasibility studies in laboratories in maritime and oil & gas settings, and in the clinic.

A close interaction with user partners ensures that all initiated projects are based on future needs in the different sectors. A large multidisciplinary research environment has been established across geographical locations (NTNU, Trondheim– UiO, Oslo – USN, Horten), which include scientists and engineers with backgrounds in acoustics, physics, mathematics, electronics, and computer science. Medical doctors and other healthcare personnel are included in clinical studies. Most of the budget is allocated to researcher training at the PhD and Postdoc level. The aim of these activities is to identify new innovations that can be brought to market by our corporate partners. The ultimate goal is that the new innovations created in CIUS will generate a large positive impact for Norwegian ultrasound research, the CIUS corporate partners and the healthcare sector.

Overarching Goals

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.

Organisation and Location

SFI CIUS is hosted by the Faculty of Medicine and Health sciences (MH) at the Norwegian University of Science and Technology (NTNU), and localised to the Department of Circulation and Medical Imaging.

Physically the academic research activity is divided across four institutions: NTNU, University of South-Eastern Norway (USN), University of Oslo (UiO), and SINTEF. SFI CIUS has 13 corporate partners: GE Vingmed Ultrasound, GE Healthcare Women's Health Ultrasound (GEWHUS), Medistim, Aurotech and EXACT Therapeutics within the medical sector; and Equinor, NDT Global, Sensorlink, InPhase Solutions and Archer BTC within the oil & gas sector: Kongsberg Maritime within the maritime sector, X-Fab for advanced analogue and mixed-signal process technologies and ReLab developing transducers across sectors. In addition, there are six user partners within the medical health provision sector: St. Olavs hospital, the Central Norway Regional Health Authority, Nord-Trøndelag Hospital Trust, Levanger and Verdal Municipalities, and Sørlandet Hospital Health Authority. CIUS also has an associated partner: the Norwegian Defence Research Establishment (FFI).

The research activity is divided into 9 work packages (WPs). USN is responsible for WP1, UiO for WP2, while WP3-7 are located to NTNU. WP8-9 are in collaboration with the industrial partners and headed by CIUS' industrial liaison. Activity connected to WP1 and WP2 is also localised to the CIUS host. There is extensive collaboration across WPs, and an iterative process between development of new technologies in WP1-4, and their validation and feasibility testing in WPs 5-9 is critical to SFI CIUS' success.

The daily activity of the centre is overseen by Centre Director Professor Asta Håberg. Further, the CIUS administration includes Industry Liaison Svein-Erik Måsøy, the Project Coordinator and Administrator Line Skarsem Reitlo, Communication and Web Officers Kari Williamson and Karl Jørgen Marthinsen and Financial Advisor/Project Economists Urszula Mochocka and Aleksandra Hvamb. Innovation in CIUS has benefited from the expertise of Innovation manager Tormod Njølstad.

Each WP has a primary investigator (PI) who oversees the respective WP's research activity. All CIUS activities are supervised and directed by a working Board of Representatives consisting of nine members with a majority from the corporate partners. The Board Leader is Eva Nilssen, Director of R&D, GE Vingmed Ultrasound.

MANAGEMENT

Board Leader Eva Nilssen,
GE Vingmed Ultrasound

Dean, Project Owner and
Board Member
Brita Solveig Pukstad, NTNU

Centre Director
Asta Håberg, NTNU

Industry Liason
Svein-Erik Måsøy, NTNU

CIUS

BOARD

ELECTED BOARD REPRESENTATIVES AMONG THE CORPORATE PARTNERS

Erik Swensen, Medistim

Petter Norli, Halfwave

APPOINTED BOARD REPRESENTATIVES

Gunnar Morken, St. Olavs hospital

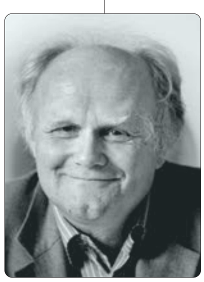
Helge Haarstad, St. Olavs hospital

Berit L. Strand, NTNU

Trym Holter, NTNU

Pål Hemmingsen, Equinor

Frank Tichy, Kongsberg Maritime



Olav Haraldseth, NTNU

SCIENTIFIC ADVISORY BOARD

Dr. Philippe Blondel, Senior Lecturer, University of Bath

Anna Shaughnessy, previous Director of Earth Resources Laboratory, MIT

Dr. Iacob Mathiesen, CSO, Otivio, Oslo

Professor Jenny Dankelman, MISIT Group, Delft University of Technology

WORK PACKAGE LEADERS


Professor Lars Hoff, USN


Professor Sverre Holm , UiO


Professor Hans Torp, NTNU


Professor Lasse Løvstakken, NTNU


Professor Asta Håberg, NTNU


Head of Cardiology
Ole Christian Mjølstad, NTNU/St.Olavs


Professor Asbjørn Støylen, NTNU

INNOVATION TEAM


Industry Liason
Svein-Erik Måsøy, NTNU


Innovation Manager
Tormod Njølstad, NTNU

WORK PACKAGE SUPERVISORS


Hefeng Dong, NTNU


Trond Ytterdal, NTNU


Tonni Franke Johansen, NTNU/Sintef


Catharina de Lange Davies, NTNU

ADMINISTRATION


Kari Williamson


Karl Jørgen Marthinsen


Urszula Mochocka


Aleksandra Hvamb


Line Skarsem Reitlo

Partners and Collaborations

CIUS has partnered with important cornerstone enterprises, SMEs, academic institutions, and the healthcare sector.

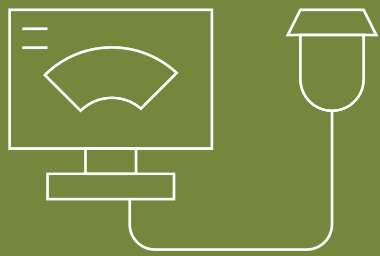
Academic Partners
Norwegian University of Science and Technology (NTNU)
SINTEF
University of Oslo (UiO)
University of South-Eastern Norway (USN)

Industry Partners
AUROTECH ultrasound AS
Archer - Bergen Technology Center
Equinor ASA
EXACT Therapeutics
GE Vingmed Ultrasound AS
GE Healthcare Women's Health Ultrasound
InPhase Solutions AS
Kongsberg Maritime Subsea AS
Medistim ASA
Sensorlink AS
X-FAB Semiconductor Foundries GmbH
ReLab
NDT Global

Health Sector Partners
Helse Midt-Norge (Central Norway Regional Health Authority)
Helse Nord-Trøndelag (Nord-Trøndelag Health Trust, Levanger Hospital)
St. Olavs hospital (Trondheim university hospital)
Innherred-samkommune (Innherred joint county primary health care)
Sørlandet sykehus HF (Sørlandet Hospital health authority)

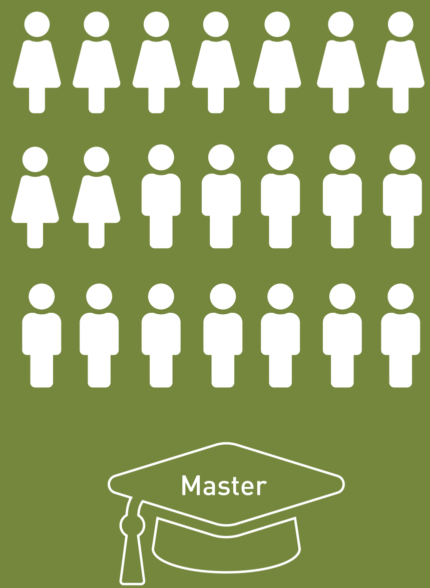
Associated Partner
Forsvarets forskningsinstitutt (Norwegian Defence Research Establishment)

Centre for
Innovative
Ultrasound
Solutions



CIUS 2021

CONFERENCE CONTRIBUTIONS: 31



INNOVATION STATISTICS

- 1 NEW PRODUCT
- 23 NEW METHODS/PROCESSES
- 2 NEW SERVICES
- 0 PATENT APPLICATIONS
- 7 DISCLOSURE OF INVENTIONS
- 58 JOURNAL AND PROCEEDINGS ARTICLES
- 5 LICENCES SIGNED WITH PARTNERS
- 1 OPEN SOURCE LICENCE

Photo: Medistim ASA

Sensorlink has success with their subsea corrosion monitoring systems based on ultrasound, and their products is continuously improved with the help from CIUS contributions. Photo: Sensorlink

1

Lars Hoff, Professor,
University of South-Eastern Norway (USN)
WP Leader

Transducer and Electronics

WP1 covers joint research for the design, fabrication, characterisation and modelling of 1D and 2D transducer arrays, integration of high-density arrays with electronics, ultrasound transducers for high pressure and high temperature environments, and multi frequency band transducers. These tasks are fundamental and highly overlapping for all applications and CIUS partners.

WP1-1: Acoustic Source Characterisation and Optimisation

Good theoretical models are essential for designing optimal ultrasound transducers. We base our work on analytical 1D equivalent circuit models and FEM simulation models. Building on existing software, we have developed an extensive software library for a variety of transducer designs, and integrated these into other software, such as optimisation algorithms. Likewise, good experimental characterisation methods are essential to investigate the designs and determine unknown parameters. The facilities at the USN MST-lab provide equipment for classic material characterisation. Through CIUS, we continue to develop dedicated systems to characterise ultrasound transducers, such as acoustic material parameters, electro-acoustic transfer function, beam pattern, and pulse shape.

WP1-2: Integrated High-performance Transducer Array Electronics

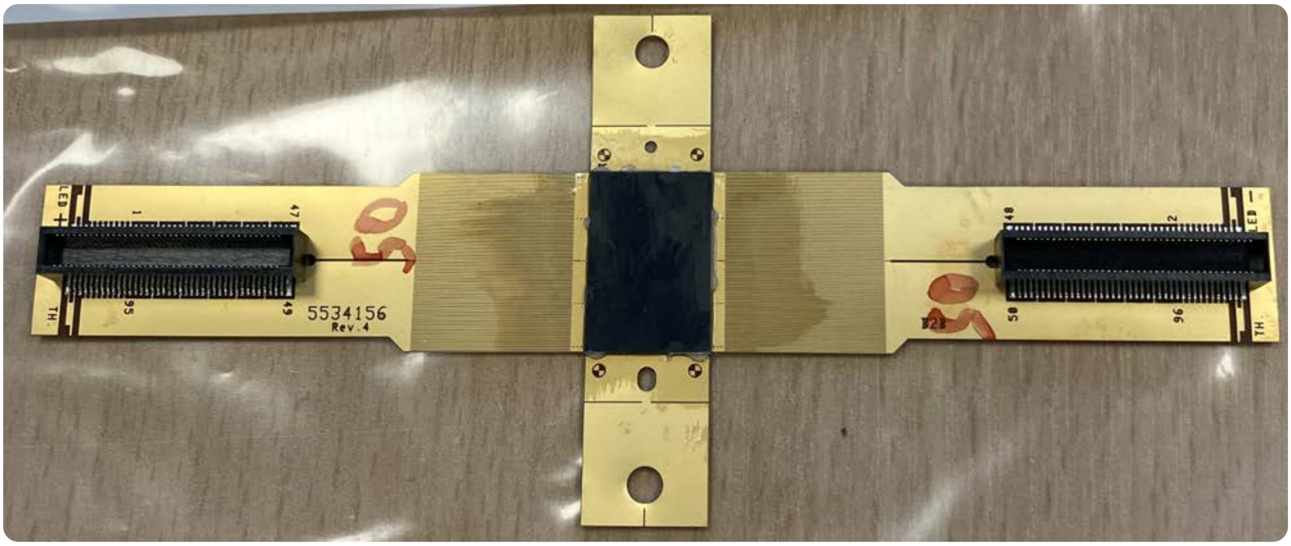
New high-density ultrasound arrays require electronics to be moved closer to the transducer. In maritime acoustics, this means moving electronics to the sonar head, while in medical ultrasound, from the scanner to the probe. A purely digital interface between the system and the transducer is preferred. In WP1, we are developing integrated circuits for low-noise receiving amplifiers, analogue-to-digital converters, and high-voltage transmitters to be integrated with the transducer inside the probe head.

WP1-3: Embedded Ultrasonic Sensors

The main emphasis in this sub-WP is on transducers that can withstand the harsh environments found in oil wells, i.e. high pressure and temperatures. We explore new materials and fabrication methods to ensure reliable operation under these conditions. The resulting improved robustness and reliability will also be beneficial for other application areas.

WP1-4: Dedicated High-frequency and Multi-Bandwidth Transducers

Combined therapeutic and diagnostic ultrasound applications require transducers covering a wider frequency range than conventional ultrasound imaging applications. The same applies to novel imaging methods based on nonlinear acoustics. We have developed new design and modelling methods for multi-band transducers and use these to develop piezoelectric transducer structures covering several frequency bands. Micromachining is another approach to achieve this performance, i.e. capacitive micromachined ultrasonic transducer (CMUT) and piezoelectric micromachined ultrasonic transducer (PMUT) technology. This can be combined



Fabrication of a hybrid piezoelectric-CMUT transducer array for medical ultrasound imaging. Work at USN in collaboration with GE Parallel Design and GE Vingmed Ultrasound. Photo: Hoang Duy Le/USN.

with a conventional piezoelectric stack to cover several frequency bands. The resulting transducers can lead to new opportunities for combined ultrasound imaging and drug-delivery systems.

Activities in 2021

The last two positions in WP1 have finally been filled, one PhD-student and one Postdoc. Three candidates who started in 2018 (two CIUS-funded and one associated industrial PhD) are now in the final stages and are expected to deliver their theses in 2022. In addition, one candidate who started in 2016 is still writing up his thesis and expected to deliver early 2022.

Development of hybrid CMUT/piezoelectric ultrasound probes for medical ultrasound imaging started in collaboration with GE Vingmed Ultrasound in 2021. This activity involves both CIUS and the RCN-funded IPN-project *Frontend and transducer technology for next generation cardiovascular ultrasound probes* (CFRON). CFRON funds one PhD-student and one 40% researcher at USN.

In addition to this, one CIUS PhD-student works in collaboration with CFRON, and USN's newly employed Postdoc has a PhD in CMUT technology and will support the project. This collaboration also includes GE Parallel Design in France, where the CIUS PhD-student is planned to spend a few weeks early 2022. The first prototypes have been designed and are being fabricated.

The INTPART project funding staff- and student-exchange with leading US universities has been delayed by Covid-19 restrictions, as visits to US universities were not possible during 2021. We hope this will change in early 2022.

The first batch of PMUTs has been fabricated and is being tested at USN. Characterisation is done using our new digital holographic microscope, giving detailed information of the shapes and vibration modes of the PMUT cells.

Three master's students at USN successfully finished their theses on ultrasound transducers during 2021, all linked to CIUS activities. One of these is now employed by the CIUS partner Kongsberg Maritime, another is a PhD Candidate at CIUS. Four master's students at IES NTNU successfully finished their theses on integrated circuits for ultrasound probes. Three PhD Candidates at IES NTNU are working together with GE Vingmed Ultrasound on integrated circuit design for in-probe electronics. The work involves both transmitters and receivers.

Activity in the ultrasound transducer lab is still high, although practical laboratory work was strongly limited by Covid-19 restrictions during the first half of the year. A Lyncee Tec digital holographic microscope was installed in September, this has proven extremely useful for investigating structures and vibrations in micromachined ultrasound transducers.

The main challenges remain as for previous years: High activity results in challenges for lab maintenance and student supervision. The CIUS-funded researchers are invaluable for our activity. Employees at industry partners contribute to supervision of the PhD Candidates, which is of essential value to ensure industry relevance.

Going Forward in 2022

Between three and five PhD Candidates will defend their theses in 2022. Assembly and initial testing of a hybrid CMUT-piezoelectric array transducer for GE Vingmed ultrasound scanners will continue. We will see results of testing and evaluation of high frequency PMUT devices.

2

Sverre Holm, Professor,
University of Oslo (UiO)
WP Leader

Acoustics and Beamforming

This work package covers fundamental research on acoustic wave propagation and image formation (beamforming) common to applications in oil & gas, maritime and medicine. Tools are developed for improved algorithms in all applications to achieve improved image resolution and contrast, higher frame rates, and improved measurement accuracy. Research systems at academic laboratories as well as computer simulations will be used to investigate next-generation imaging based on channel data processing that will provide a strong basis for innovation for the user partners. The WP provides knowledge and tools for other WPs and thus enables their impact on the industrial partners and healthcare providers.

WP2-1. UltraSound Toolbox (USTB)

This project focuses on joint development of the UltraSound Toolbox (USTB), www.ustb.no, an open-source software toolbox for processing ultrasonic signals. It aims to facilitate the comparison of imaging techniques and thereby generalisability and dissemination of research results. USTB covers processing techniques for tissue and flow visualisation, as well as other image reconstruction techniques. USTB is a central component in the new course Ultrasound Imaging (IN4015) at UIO. We have also, through internal funding in SINTEF, bridged the USTB together with FAST in collaboration with CIUS researchers Erik Smistad and Andreas Østvik. Similarly, examples using the FlowLine Ultrasound Simulation Tool (FLUST) have been included. Two journal articles are currently being written using the USTB for beamforming.

WP2-2. Ultrasound Non-destructive Testing (NDT) methods

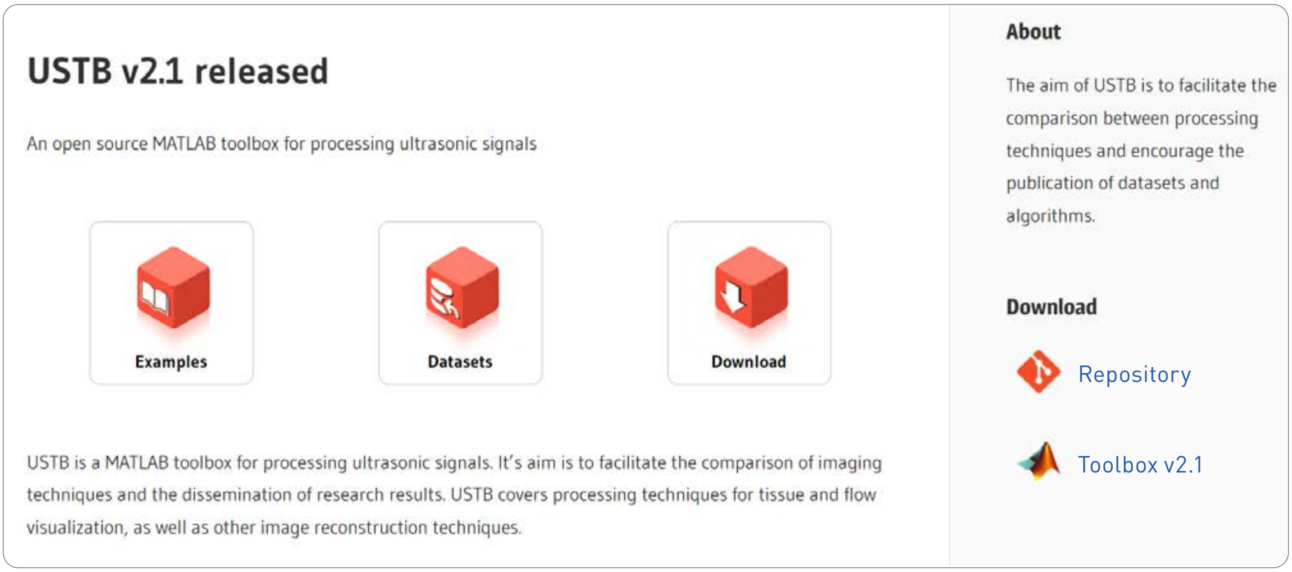
Here we use ultrasonic NDT methods to find information about a flowing fluid with solid particles outside a pipe or a plate, to find the properties of cement on the outside of a pipe, to detect cracks in a solid pipe, and to obtain general information about the state of a pipe in terms of e.g. cracks and corrosion. *In 2021,* a project for monitoring of pipe corrosion supported by machine learning was started with Magnus Wangensten as a PhD student. Furthermore, UiO has a new internally funded PhD research fellow, Håvard Kjellmo Arnestad in the project "Wavefields and spectral estimation in acoustic imaging".

WP2-3: Multibeam Sonar Imaging with Nonlinear Acoustics

Here we investigate the feasibility of utilising the part of the signal generated around the second harmonic frequency band by nonlinear propagation of sound in water. No activity has taken place in 2021, according to plan.

WP2-4: Adaptive Image Formation for Improved Image Quality

This work focuses on developing a method for adaptively improving image quality in echocardiography. This means using patient-dependent processing in the ultrasound system, adapting the image quality and processing in the ultrasound scanner to each individual patient. The goal is to improve image quality with the potential of improving diagnosis and patient follow-up. A journal article is in the final preparations for submission, presenting a quantitative metric for in-vivo cardiac images, which has previously been reported in a DOFI. A DOFI on a new adaptive image formation technique was sent to the CIUS consortium in 2020 and a CIUS partner has chosen to license this technology in 2021.



WP2-5: Improved Mapping Rate in Seabed Mapping with Sonar

Recent development in sonar technology allows for more flexible array design, and greater frequency agility. The development of high-performance computing in small formfactors also allows for using substantially more complex signal processing.

Taking these factors into account, a re-visit of the fundamentals in signal processing in certain advanced sonar applications is studied. This activity is now completed with the defence of Antoine Blachet's thesis "Swath sonar: Advanced waveform modulation and associated signal processing techniques" at UiO in May 2021.

The paper "Multibeam Echosounder with Orthogonal Waveforms: Feasibility and Potential Benefits," IEEE J. Oceanic Engineering was published.

The FFI funded PhD research fellow Ole Jacob Lorenzen, who started the UiO PhD programme in 2020 with the project "Synthetic Aperture Sonar Interferometry in Rough Seafloor Bathymetry." UiO has a new PhD research fellow, Gabor Gereb, in a collaboration with Kongsberg Maritime on "Adaptive beam-forming in underwater detection and estimation problems."

WP2-6: Suppression of Reverberation Artifacts in Ultrasound Imaging

Patients with a high body mass index (BMI) often have an impaired acoustic window that is translated into aberration and reverberation artifacts. This project aims to understand and correct the factors that lead to reverberation artifacts, such as secondary out-of plane reflections from ribs/lungs. This project has ended and Ali Fatemi, delivered his PhD thesis in 2021 and will defend it in January 2022.

WP2-7: Ultrasound Elastography with Harmonic Source for Cardiology

Here we explore the potential of the MR approach with an external vibration source for ultrasound elastography, as it has the potential for e.g. deeper penetration and more accurate reconstruction. The activity in this project was completed in 2020.

Going Forward in 2022

The development of the UltraSound Toolbox will continue as well as its integration with other CIUS-developed tools. The experimental setup for corrosion analysis will be developed further in WP2-2. Two PhD theses will be defended.

3

Hans Torp, Professor, NTNU
WP Leader

Doppler and Deformation Imaging

Technology to improve methods for detecting and measuring flow and displacements in ultrasound images. This ability is considered one of the main strengths of US compared to other image modalities and is fundamental to several of CIUS' innovation goals.

WP3-1: Three-dimensional Vector-flow Imaging

The traditional Doppler imaging approach is limited in terms of measurement range and is inherently one-dimensional. We will develop and utilise next-generation multi-dimensional imaging of blood velocities, enabled by utilising the increased data information available using parallel acquisition techniques. The focus will be on achieving real-time 3D (full velocity vector) imaging of blood velocities, based on spectral- and colour-Doppler imaging.

In 2021, intraventricular vector flow imaging has been further developed in Trondheim, and clinical studies in children have been performed at the SickKids Hospital, Toronto, and in adults at NTNU, Trondheim.

An INTPART application: 'Yield of Ultrasound for the Next Generation (YOUNG) – Heart and Brain interactions in children' has been granted. The aim is to strengthen the scientific collaboration between NTNU/CIUS and SickKids Hospital, Toronto. A start-up meeting with participants from Toronto and NTNU was held in Trondheim on 15 December 2021.

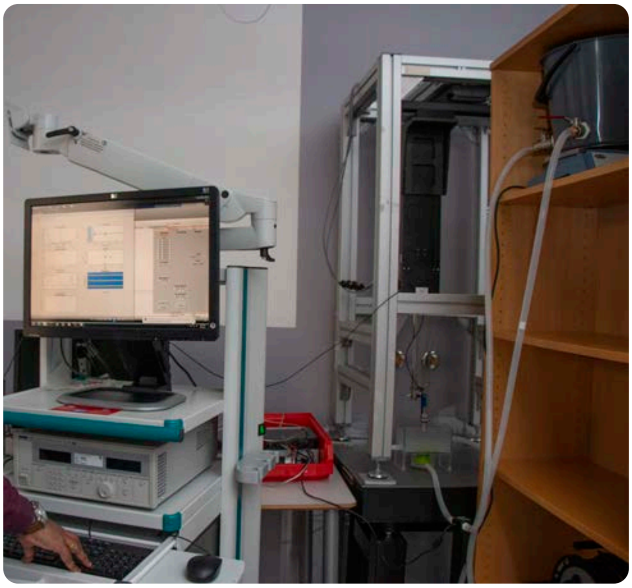
In the 'Intraventricular pressure gradients' project, data from 179 healthy children at Ålesund hospital has been analysed, and results have been presented at international conferences in Leuven, Belgium, and in the USA (the ASE Conference).

3D flow quantification of valve leakage has been further developed by deep learning methods, and extensive in vitro testing in 2021. The method is still hampered by technical limitations in current 3D probe technology, resulting in poor performance in a clinical feasibility study, with limited possibility for publication.

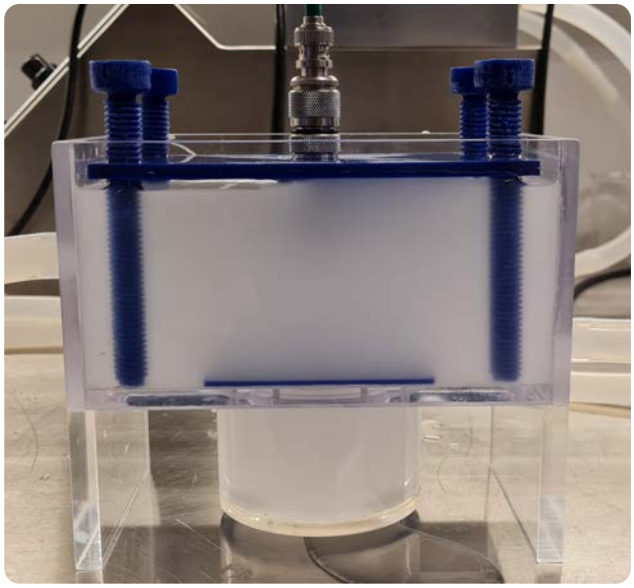
WP3-2: Flow Measurement in Non-stationary and Noisy Surroundings

The PhD Candidate Shivanandan Indimath started working in January 2021 and has created a simplified experimental setup of emulation influx/efflux in a borehole situation in the ultrasound lab at ISB.

The setup is, as stated, simple and is currently using water and corn starch to emulate the drilling fluid. The project has looked at adapting transducers to the flow setup and purchased suitable transducers with the ISB lab versatile ultrasound research system. Indimath has created a setup where it is possible to emulate various influx/efflux scenarios by changing flow volumes and orifice geometries. Several Doppler processing algorithms have been developed and a first journal paper is now being produced where a large parameter space is being mapped out experimentally. This shows the potential of ultrasound Doppler imaging to detect various flow conditions in a logging-while-drilling operation.



Experimental setup for estimating flow influx/efflux in oil and gas boreholes using pulse-wave Doppler ultrasound. Photo: Kari Williamson/NTNU



Flow cell mimicking influx/efflux of drilling fluid from fractures in the borehole wall. An ultrasound transducer used for pulse-wave Doppler estimation of the influx/efflux is mounted in a position mimicking the logging-while-drilling (LWD) tool. Photo: Shivanandan Indimath/NTNU

WP3-3: High Frame Rate Tissue Deformation Imaging

The development of acquisition strategies and processing algorithms for high frame-rate 3D tissue deformation imaging, utilises the increased data information available using parallel acquisition techniques. The overall aim is to evaluate regions with specific properties such as increased stiffness or reduced muscle contraction. Methods will be based on Doppler, speckle tracking, and acoustic radiation force principles (e.g. shear wave elastography).

3D myocardial mapping of mechanical waves by "clutter filter wave imaging" has received much attention and is now published in the high ranked journal JACC Cardiovascular Imaging. Analysis of data from 100 patients with myocardial fibrosis is in progress; preliminary results have been presented at an international conference in 2021 and will result in a journal paper in 2022.

WP3-4: Doppler Imaging of Flow in Cement behind Steel Casing

For the oil & gas well integrity logging operations, detecting flow in the cemented zonal isolation layers is of vital interest. Currently this is not possible with state-of-the-art US logging tools. This project will use lab models of cemented wells and develop new ultrasound Doppler techniques for flow detection in the cement behind steel casing. There has been no activity in this sub-project in 2021, and there is no planned activity for 2022.

Going Forward in 2022

Four papers are planned for submission in 2022, two on WP3-1 and one in WP3-2 and WP3-3, respectively. Additional planned activities not mentioned above are listed below, sorted by project:

WP3-1: We are planning to improve the acquisition setup using valve leakage quantification to improve clinical feasibility. If we have enough resources, we will expand the deep learning methods from 2D to 3D.

WP3-2: We are currently developing a more realistic experimental facility at SINTEF's petroleum engineering lab using real drilling fluids and more realistic flow conditions. Deep learning method from WP3-1 is under evaluation for characterisation of sub-resolution orifices in boreholes. We will also shortly initiate experiments to characterise micro-bubbles in the flow as an early kick detection system for logging-while-drilling.

WP3-3: Initial results from mechanical wave mapping from patient data are promising. We will continue to develop and validate this method.

4

Lasse Løvstakken, Professor, NTNU
WP Leader

Image Analysis and Visualisation

This work package covers the development of image processing and analysis methods to extract relevant contextual information from ultrasound image data, to improve measurement quality, and to provide a more efficient workflow to reduce the time to decision. These tasks are also coupled to enhanced data visualisation to improve data exploration and interaction.

Challenges in medical, maritime, and industrial applications are addressed using modern approaches in signal and image processing, with emphasis on recent machine learning algorithms (e.g., deep learning) for classification and extraction of data and image features. The work package outcome will provide improved extraction of relevant high-level information in the data, and improved data acquisition and processing at lower levels by providing an initial interpretation of the problem.

Our research aims support the main innovation goals defined in CIUS, such as ultrasound-based anatomical and functional medical imaging, improved seabed classification, and improved well integrity monitoring. The current activities also support a broader usage and have relevance for other work packages. For instance, image analysis methods developed for cardiac imaging are well suited for automated measurements, and for quality control during data acquisition, which are topics of high relevance for WP6.

The Current Updated Work Package Tasks are:

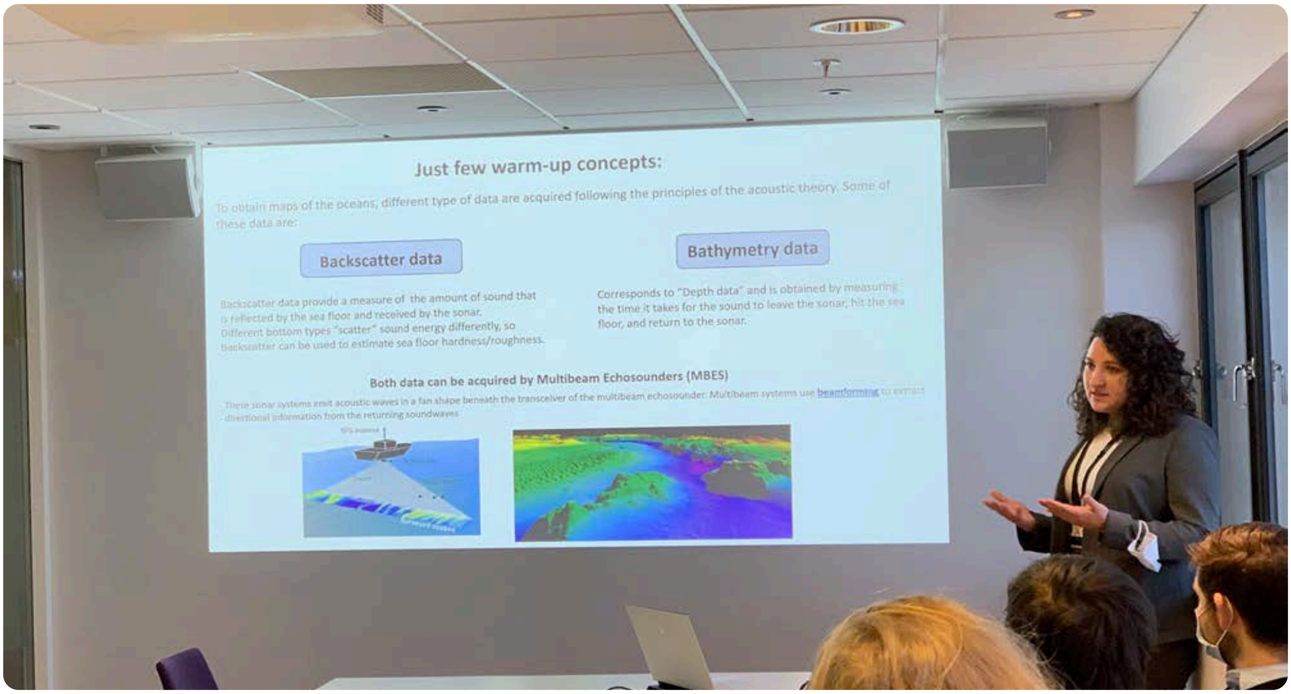
- WP4-1: Automatic anatomical and functional measurements in echocardiography
- WP4-2: Improved detection of pores and cracks in downhole logging
- WP4-3: Machine learning for automatic seabed mapping
- WP4-4: Machine learning for automatic maturation grading in Atlantic salmon

These tasks have common challenges and can be addressed by common data and image processing approaches. The initial aim was to establish a state-of-the-art framework and expertise in machine learning algorithms trained to recognise and segment relevant image or data features.

Further, we aim to develop a model-based estimation framework for regularisation and reconstruction of noisy and potentially missing image information based on physical models, a pathway towards more robust measurements. Finally, to explore how these methods can provide context for improved data acquisition and measurements.

Activities in 2021

The year 2021 was productive for WP4, with publications published in both medical and industrial domains. Our efforts have been noticed abroad and we are being invited to present at relevant conferences. Two DOFIs were submitted in the medical domain.



PhD-candidate Rosa Virginia Garone presenting at the CIUS Fall Seminar 2022. Photo: Kari Williamson/NTNU.

Going Forward in 2022

In 2022 we will continue our work on integrating AI in the echo lab and develop methods for simplifying cardiac echo acquisition outside the hospital setting. We will see results from our recent industrial projects, a PhD project on seabed classification, and a PhD project on AI analysis for evaluating salmon development/ maturation. We will continue our efforts of using machine learning in oil & gas well logging in collaboration with Equinor.

Real-time demos for GE Vingmed.

5

Asta Håberg, Professor, NTNU
WP Leader

Multimodality and Interventional Imaging

In WP5, the focus is on development and application of multimodal and interventional imaging for improved diagnostic, treatment and follow-up. Multimodal imaging combines the strengths of different modalities such as ultrasound, MR, CT, and PET for diagnosis and follow-up, as well as for guidance during surgery, targeted drug-delivery, and other therapeutic procedures.

WP5-1 & WP5-2: Multimodal Imaging and 3D Volume Registration in Cardiology and Image Guided Surgery

We aim to continue the development of a robust system, utilising artificial intelligence for automatic functional monitoring of the heart by ultrasound recordings of the left ventricle (LV). Furthermore, we plan to add the time series view to mitral and tricuspid tracking. Currently the main focus of our work has been on detection of the mitral valve. We want to go a step further, and by using artificial intelligence, build a strong system that can follow points of the leaflets over time first in 2D, then 3D. This will help stabilise the landmark prediction on a continuous sequence and allow automatic calculation of relevant measurements more accurately.

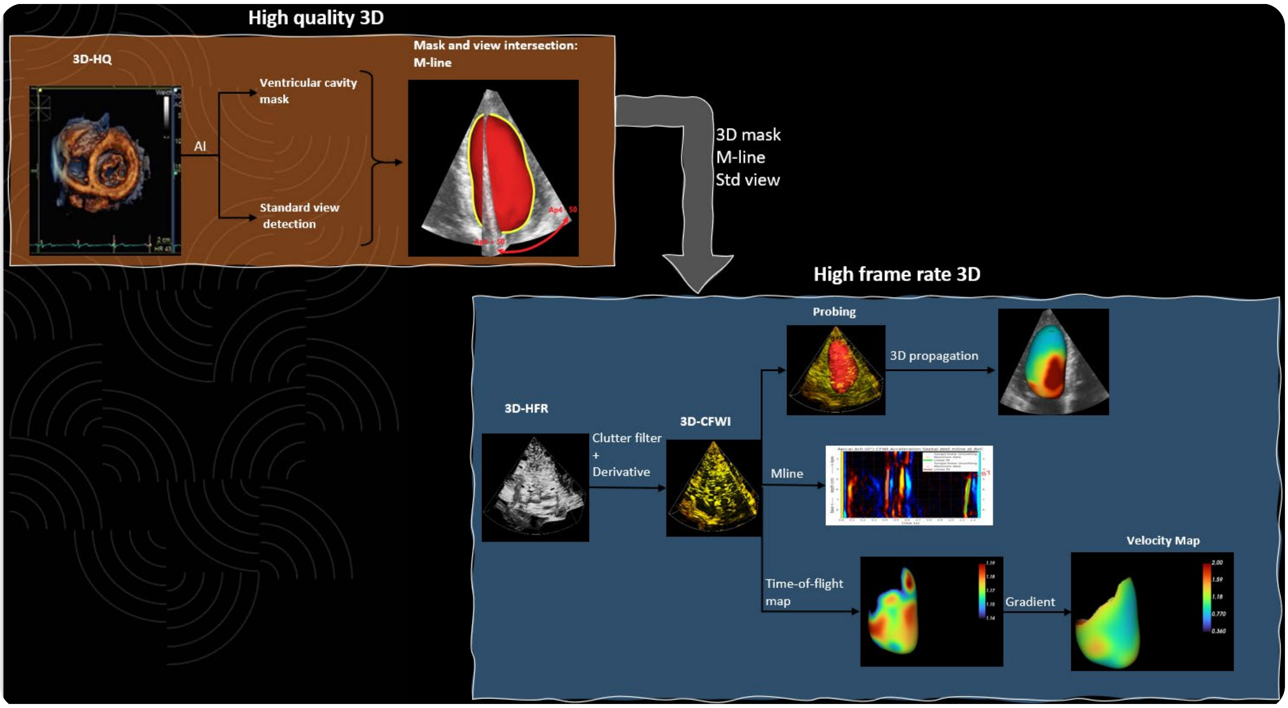
WP5-3: Multimodal US and PET-MR for Improved Diagnosis in Brain and Heart Disease

Hybrid PET/MRI scanners combine the superior soft tissue images from MRI with molecular imaging capabilities provided by PET scans in diagnosis of disease, as well as for increased understanding of disease mechanisms and pathophysiology. A new amino acid PET tracer ^{18}F-FACBC was tested for its sensitivity and applicability detection of brain tumour metastasis, and it demonstrated high and specific uptake even in a very small cerebellar metastasis otherwise overlooked. Further studies are underway to determine the threshold for ^{18}F-FACBC brain tumour boundaries, and relationships between this amino acid tracer uptake and molecular characteristics of the tumours based on biopsies obtained by image-guided navigated surgery.

The start of local PET tau tracer production went according to plan in 2021 and approval by the Norwegian Medicines Agency will hopefully be obtained in 2022 allowing for the first tau PET scans to be acquired in the autumn of 2022.

WP5-4: Ultrasound -mediated Drug Delivery

A prerequisite for successful pharmacological cancer therapy is that the therapeutic agent reaches all tumour cells and kill them. Unfortunately, the uptake of drugs into tumours is low. Encapsulating drugs in nanoparticles can increase the tumour uptake, but even nanoparticles have low and variable uptake in tumour tissue. Focused ultrasound combined with microbubbles has been reported to improve the delivery of nanoparticles as well as free drugs in tumours, improving the therapeutic effect. This project systematically examines different aspects of focused ultrasound combined with microbubbles for improved treatment of tumours to understand mechanisms for the successful therapeutic effect. The hypothesis that Acoustic Cluster Therapy (ACT) induces an immune response and changes perfusion was studied in preclinical models. Successful delivery of nanoparticles across the blood brain barrier after ACT treatment was achieved. This result is encouraging for treating diseases in the brain.



Semi-automatic pipeline that uses artificial intelligence to construct ventricular segmentation and to find three apical standard views (4-chamber, 2-chamber, long-axis). This information is then used to extract velocity values from CFWI data using M-mode and gradient methods. Image: Danial (Mohammad) Mohajery/NTNU

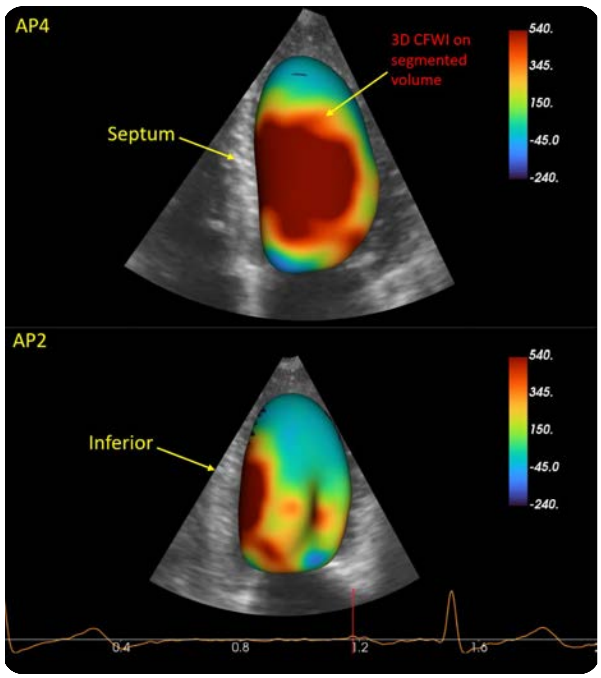
At St. Olavs hospital, two clinical studies implement focused ultrasound and microbubbles combined with standard chemo-therapy for treatment of liver metastasis and in patients with pancreatic cancer. The results of these studies are currently being processed.

Going Forward in 2022

In WP5-1&2, we will continue to develop our system for automatic functional monitoring of the heart using ultrasound recordings and state-of-the-art convolutional neural networks (CNN). We will also be testing and validating our method in different clinical environments, both during surgery and in the intensive care unit. Ultimately, the goal is that automatic ultrasound monitoring of the heart will provide information that may predict and potentially improve clinical outcome.

In WP5-3, we have several PET-MRI studies in the pipeline. The most novel is an interventional clinical theranostic study in patients with glioma to improve diagnostic imaging and at the same time treat the cancer using ^{68}Ga/^{177}Lu-PSMA, a novel, well-tolerated radionuclide that might increase overall survival and quality of life in these patients with very short expected survival.

In WP5-4, results will be published on tumour biomarkers determining the success of ACT and mechanisms to exploit and improve the efficacy of ACT. New studies to better understand the transportation of nanoparticles through extracellular matrix and how to use ultrasound to improve transport, will be started.



Visualisation of the atrial-kick wave with CFWI data on the ventricular segmentation seen from two apical views (4-chamber and 2-chamber) Image: Danial (Mohammad) Mohajery/NTNU

6

Ole Christian Mjølstad, Head of Cardiology, St. Olavs University Hospital Trondheim and NTNU WP Leader

Ubiquitous Ultrasound

Pocket-sized ultrasound devices are extremely portable and have now been implemented as part of the diagnostics of patients – from rural district hospitals to nursing homes in the Western world. Development of easy-to-use ultrasound technology has significant innovation potential and can be a paradigm shift for practices in the healthcare sector, where the goal is to offer patients more rapid diagnosis outside of hospitals, as well as to avoid unnecessary hospital admissions.

WP6-1 Multi–Purpose Ultrasound Imaging for Non-experts

This sub-WP focuses on the:

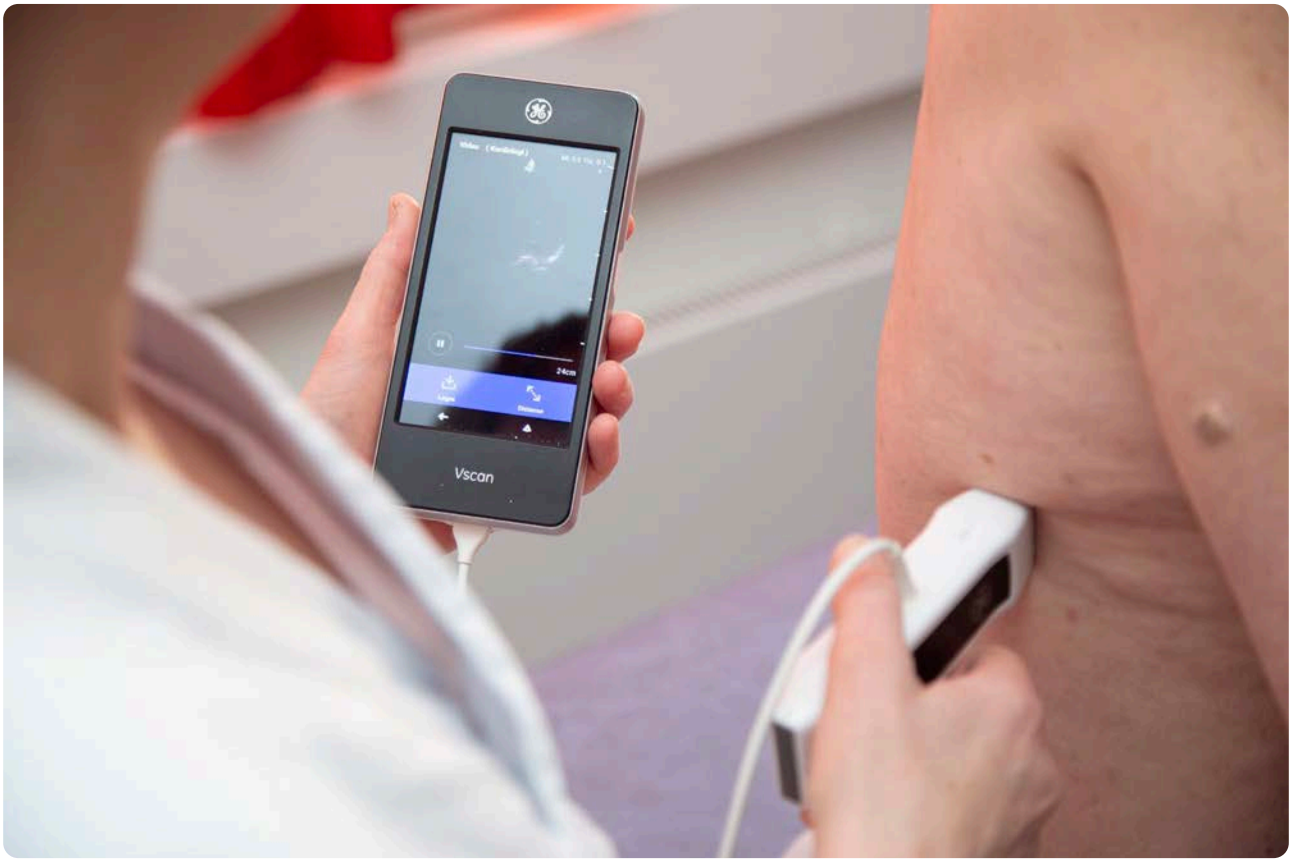
- Technical development and clinical feasibility of using pocket-sized ultrasound.
- Clinical use, automated methods for navigational aid and (semi)automatic measurements (e.g. organ size, displacements).

We develop and validate tools targeting non-expert personnel but will also find use in high-end systems when successful.

At NTNU / Levanger Hospital, we have performed training of general practitioners (GPs) that provide services in nursing homes. The GPs were trained in focused cardiac ultrasound aiming to detect heart failure and fluid overload. They have assessed and scanned patients with pocket-sized ultrasound in a heart failure outpatient clinic and transferred the recordings to a cardiologist with a telemedicine system.

Project Updates

- The feasibility and accuracy study of automatic tools for quantitative analyses of left ventricular size and function by hand-held ultrasound systems and the use of telemedicine: Inclusion and data collection were completed in 2020.
- The clinical GP study: The study includes evaluation of 1) Standardised education of GPs for assessment of left ventricle function, 2) Automatic software for analysis of left ventricular function integrated in pocket-sized ultrasound device; and 3) Support of inexperienced users by telemedicine. Our industrial partner GE Vingmed Ultrasound has provided five Vscan Extend devices for the study. Two papers were submitted in December 2021 and two more papers are now finalised.
- Evaluation of AI algorithms used in real-time during scanning to reduce left ventricular foreshortening, improve standardisation and reduce user related variation: This study is the first clinical step towards real-time guidance of the operator during scanning. Inclusion of participants for this study ended in 2021. Two papers to be submitted in 2022.
- Evaluation of AI algorithms used in real-time during scanning to improve alignment of the left ventricle, improve standardisation and reduce user related variation: This study is evaluating real-time guidance of the operator. Inclusion is ongoing winter 2022. Two papers to be submitted in 2022-23.
- Updated normal reference data for automatic measurements: Automatic analysis of large established datasets by AI tools that can be implemented on the hand-held ultrasound platform is planned for submission in 2022.
- Pocket-sized ultrasound for rapid diagnoses in stroke/transient ischemic attack (TIA) patients: This is a study conducted in Levanger Hospital with a Vscan with a Dual probe. There has been some delay in this project due to the Covid-19 pandemic. Two papers were published in 2021.



GPs have been trained in using handheld ultrasound devices at NTNU/Levanger Hospital. Photo: Karl Jørgen Marthinsen/NTNU.

WP6-2 Clinical Benefit of use of Pocket-sized Ultrasound Imaging in Nursing Homes

This part was merged into WP 6-1 as the physicians at the nursing homes at our partners Levanger and Verdal municipalities were those selected from the partners to join the clinical GP study.

WP6-3 Automatic Detection of Signs of Rheumatic Heart Disease

Approximately 8-15 million children worldwide are affected by rheumatic fever and rheumatic heart disease. These are conditions that lead to significant valvular regurgitation and stenosis. This project planned to evaluate pocket-sized ultrasound for the screening of children in Nepal, Australia or other countries with high incidence of infectious valvular disease.

The collaboration with Brisbane, Australia was postponed several times due to reasons outside our centre, and has now been cancelled, as it is not realistic to be performed due to the pandemic.

Going Forward in 2022

We will plan for the evaluation of real-time guidance on the hand-held platform when we have developed the technology needed.

PhD candidate MSc David Pasdeloup will continue with machine learning and AI in cooperation with Professor Lasse Løvstakken (NTNU) and Sigmund Frigstad (GE Healthcare) to develop technology for quality assurance of echo images and computer-assisted guidance for cardiac applications.

PhD candidates Malgorzata Isabela Magelssen and Anne Hjorth-Hansen will finalise the submission of manuscripts. The submission of papers will be the main issue for the coming period.

PhD candidate Lars Mølgaard Saxhaug is in the process of publishing his third article. PhD candidate Håkon Nergaard Pettersen and research student Sigbjørn Sæbø will collect data and publish their first manuscripts on real-time guidance of the operator during echocardiographic scanning.

7

Asbjørn Støylen, Professor, NTNU
WP Leader

Clinical Feasibility

This work package focuses on clinical assessment of new technical ultrasound modalities for evaluation of coronary disease and congenital heart disease.

Clinical Assessment of New Technical Ultrasound Modalities for Evaluation of Coronary Disease

Coronary heart disease is still the largest single cause of death, as well as being treatment-cost-intensive. Early invasive treatment in the acute phase of an infarct is the main cause for treatment-related reduced mortality. The challenges are to develop more effective diagnostic modalities to assess infarcts, both in the acute and late phase, to select patients to the appropriate treatment in the acute phase to minimise organ damage, and at the same time reduce the number of unnecessary procedures. The emphasis is on quantitative ultrasound methods using new technology, especially 3/4D ultrasound for deformation and flow. This has significant development potential and can be a paradigm for quicker pre- and early in-hospital assessment and selection. In addition, the identification of viable myocardium after an infarct is of importance for maintaining optimal heart function, while at the same time identifying patients who will not profit from invasive treatment to avoid unnecessary treatment. Clinical research, however, depends on the establishment of the new methods, primary development is technical, while clinicians enter in later stages of testing in vivo, as well as evaluating findings in terms of function.

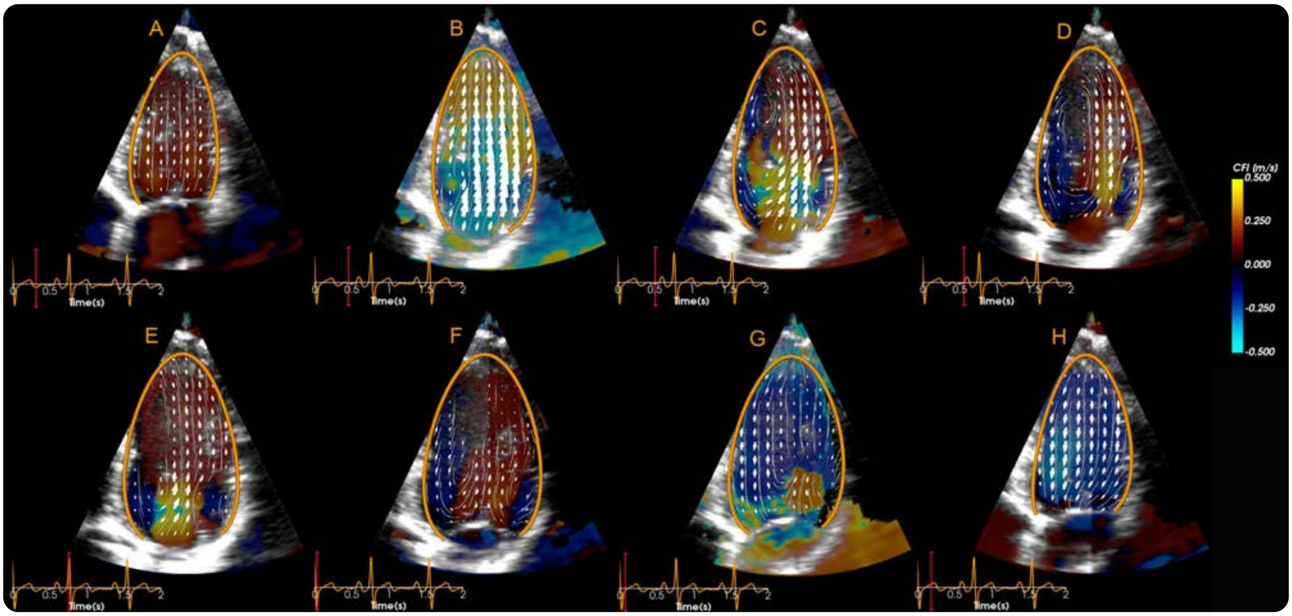
WP7-1 Ultrasound Coronary Angiography and Cardiac Flow – Feasibility and Validation

The main aim of this project is to assess the feasibility of new 3D methods for visualising coronary arteries, and quantification of coronary stenosis with Doppler. The methods will be compared to coronary angiography with fractional flow reserve.

The WP resources have been diverted to flow vector imaging (clinical). The primary objective of 3D ultrasound coronary imaging has thus not been started. However, in collaboration with a project centring on CT anatomical and functional assessment of coronary arteries, a stress echo study utilising a new, high-end scanner with increased resolution and frame rate has been started to evaluate speckle tracking stress echocardiography as a functional test for coronary perfusion. This has not been feasible by any scanner generation previously, and therefore lacks clinical data. The analysis is under way.

WP7-2 and 7-3 Ultrasound Based Markers of Ischemia and Viability in Patients with Myocardial Infarction

Acute ischemia and viability were originally in two different work packages, but the projects have been merged. In the acute phase, acute infarcts may present without characteristic ECG changes, although research have shown that at least 1/3 of patients without these changes have an occluded infarct related artery. Due to the lack of specific ECG changes, they will miss early invasive treatment, which will lead to larger infarcts and worse prognosis. Using newer physiological markers of ischemia



Multiple frames throughout the heart cycle, showing intraventricular vortex formation during the different phases of the heart cycle, based on blood speckle tracking in a normal subject. Illustration: Annichen Søyland Daae/NTNU. From: Daae et.al. Intraventricular Vector Flow Imaging with Blood Speckle Tracking in Adults: Feasibility, Normal Physiology and Mechanisms in Healthy Volunteers. Ultrasound Med Biol. 2021 Dec;47(12):3501-3513.

in combination with 3D deformation imaging, will make it possible to quantitate "myocardial area at risk", to identify these patients for early treatment. The same parameters can be used to evaluate the extent of myocardial scarring, where extensive scarring in the late phase precludes the effect of invasive treatment. The aim of this WP is to validate the assessment of acute ischemia and scarring in 3D reconstructed images against references (coronary angiography and MR scar imaging). One paper is submitted, one paper is under preparation. The further aim is to take this into real-time 3D deformation imaging (Cf. WP 3-3)

The project has one full-time PhD Student. The analysis tool is finished for reconstruction of a 3D plane model from 2D tissue Doppler echocardiography. Analysis is finished in the chronic infarct population and the acute study, and the analysis tool based on high framerate 3D tissue Doppler acquisition has been developed. Old data has shown low feasibility for 3D measurement. HFR 3D tissue Doppler is being developed, and will be useful for measuring both contraction, stiffness and elasticity in acute infarcts.

Additional Projects in WP7

Prehospital Diagnosis and Risk Stratification of Acute Coronary Syndrome
In cooperation with Sørlandet hospital. The project has suffered from the fact that the PhD Candidates have left, but patients have still been included, and is now finished with 250 patients included. One manuscript is under review, and data has been analysed and interpreted at NTNU by CIUS Research fellow Bjørnar Grenne.

Intracardiac Flow and Congenital Heart Disease
In this clinical WP, an additional project based on 2D and 3D vector flow imaging (CF. WP 3.1) to visualise abnormal intracardiac flow in children have been started under WP7 (3D flow quantification congenital).

The project on congenital heart disease has one PhD Student, and one part time Guest Researcher. Inclusion of patients at Sick Children's Hospital in Toronto is ongoing.

A new PhD has been employed in the same field, with external funding.

In addition, the technique is being tested for feasibility in adults, in a cooperative project, with ISB (3D flow quantification acquired).

The project on intracardiac flow in adults has included the healthy volunteers in the pilot study, and analysis is ongoing on:

- The physiology of intraventricular flow in normal subjects
- Retrospective tissue Doppler and Doppler in normal subjects
- Changes in intraventricular flow pattern in heart failure, both with concentric and dilated ventricles.

Going Forward in 2022

- Clinical study: Real-time 3D deformation imaging in infarcts.
- Further clinical studies in blood speckle tracking: New technical solutions.
- Publication of unpublished materials.

8|9

Svein-Erik Måsøy, Industry Liaison and Researcher, NTNU
WP Leader

Piloting in the Maritime and Oil & Gas Fields

This work package follows feasibility, piloting, and validation of CIUS developed innovations in the maritime and oil & gas sector. In these fields, field trials, demos, equipment, and systems are very expensive and require the partners to take the lead with support from CIUS researchers.

Activities in 2021

Although the pandemic has challenged CIUS, many projects have been able to move forward more or less as planned. A selection of the ongoing projects is reported here.

Oil & Gas

A pilot project on assisted interpretation of cement evaluation logs using machine learning was started in 2021. Equinor funds this project through a framework agreement with NTNU, providing 50% funding for CIUS researcher Erlend Magnus Viggen to collaborate with Equinor personnel on building a tool to assist interpreters, based on up-to-date internal Equinor data that has undergone a thorough quality control process. This tool is based on research done in CIUS and Equinor, with various improvements and extensions including integration with the software tool used by well log interpreters. Current quantitative results are very promising, and an alpha version of the tool is currently being tested by users in Equinor.

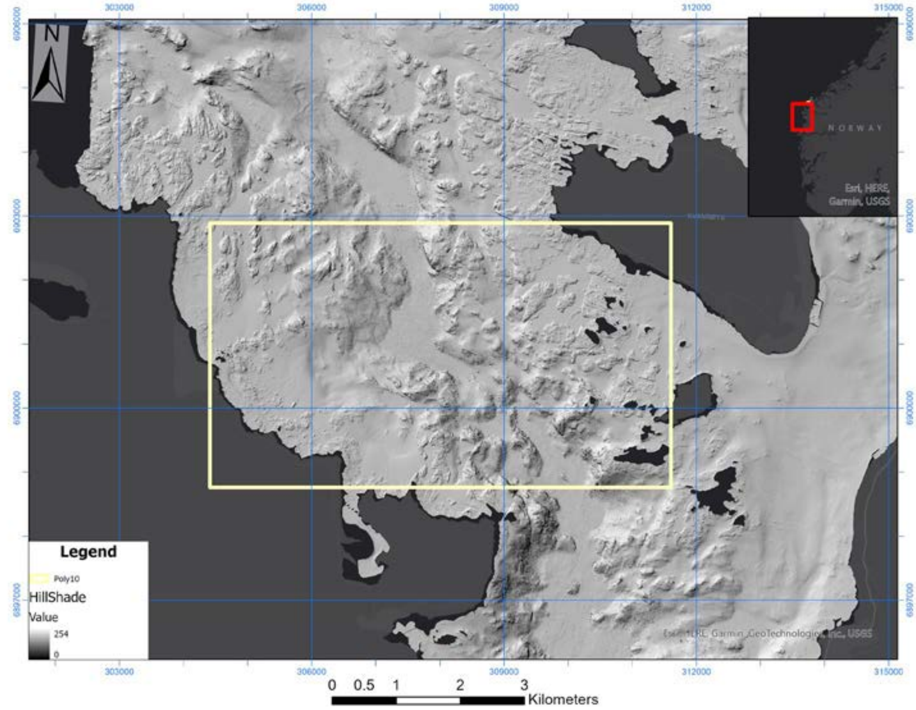
CIUS partner Sensorlink is developing new technology for increased sensitivity and detailed diagnosis of corroded oil and gas pipes using ultrasound. An experimental setup has been established in Sensorlink's facilities. The setup will be used for development of a prototype system for pilot testing. It has also been used in the accompanying PhD project of Magnus Wangensteen, for experimental verification of simulations.

Maritime

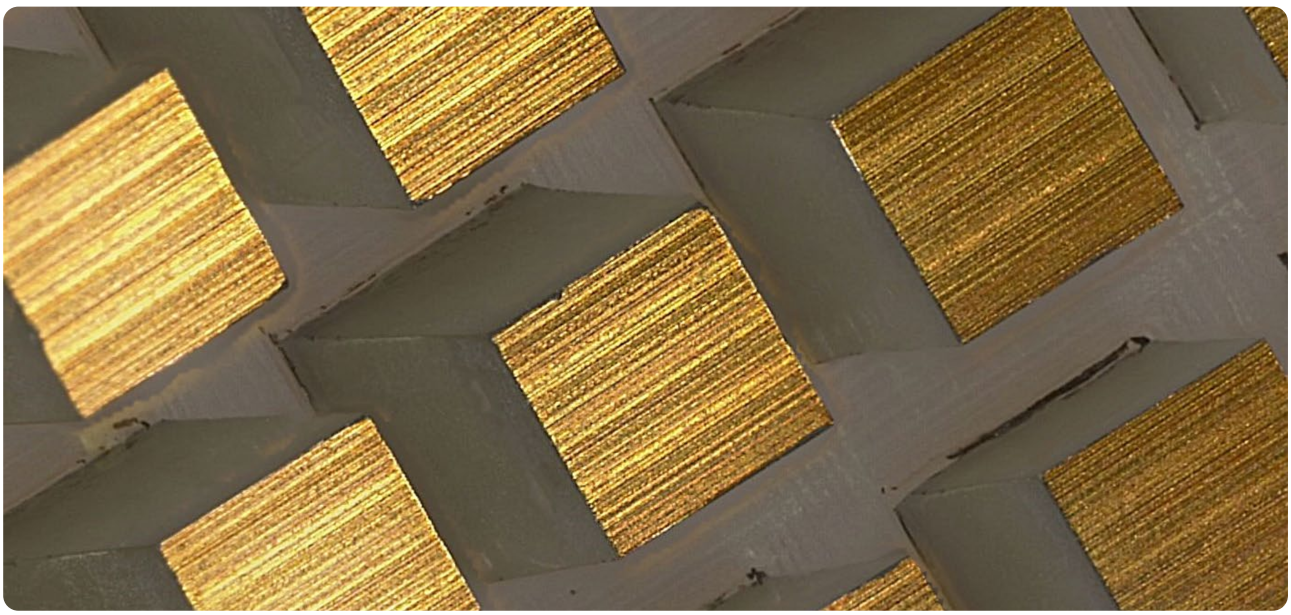
Ellen Sagaas Røed is an Industrial PhD Candidate at USN and has successfully fabricated a new single crystal piezocomposite transducer at Kongsberg Maritime in Horten. The transducer has a usable bandwidth of 132% relative to the centre frequency, which represents a significant improvement in bandwidth compared to conventional transducers. This is a great achievement and will potentially lead to increase sensitivity and resolution of future sonars.

In collaboration between CIUS, Kongsberg Maritime and The Geological Survey of Norway (NGU), a project on piloting seabed classification using machine learning on simulated and realistic data has been started. In 2021, a first large dataset has been collected and prepared. Classification methods from medical ultrasound has been tested on parts of this dataset. Initial results are promising, and the project moves forward with the aim of significantly reducing the workload on seabed classification.

In a joint project between CIUS, CIUS partner InPhase Solutions, AquaGen and Mowi a large dataset has been collected for ultrasound machine learning based monitoring of maturation states of Atlantic salmon (see the pr*ofile story on Yasin Yari p. 38).*



Shaded relief image of the seafloor, modelled from bathimetry, with a reference yellow framed area. Image: Rosa Garone, NGU.



Elements of single crystal piezocomposite transducer during manufacturing. Photo: Ellen Sagaas Røed/Kongsberg Maritime.

Photo: GE Healthcare Women's Health Ultrasound (GEWHUS).

Stories

Part of CIUS' success in innovation stems from our ability to work across subject fields, and across the professional 'barriers' between industry, academia and medicine.

CIUS has had a broad range of research projects from the start, but in 2021, we went even further with new partner GE Healthcare Women's Health Ultrasound (GEWHUS) and a new PhD working with ultrasound in fish farming. We also get insights into further developments in transducers, sonars, and cardiac ultrasound.

Ultrasound on a Chip
Amirfereydoon Mansoori is close to finishing his PhD at USN on modelling, design, and characterization of piezoelectric micromachined ultrasonic transducers (PMUTs). He looks at the limitations and potentials of these tiny devices and talks about how he has benefited from internships in industry.

Ultrasound and AI Improve Salmon Breeding and Welfare
This story explores the new CIUS topic of ultrasound in fish farming. Yasin Yari recently started his PhD at NTNU and will work on using machine learning and ultrasound to automate and improve the accuracy of finding the optimal timing for egg harvesting for salmon breeding.

Spotting Small Objects on the Seafloor
The seabed is not a flat, smooth surface, something which can provide challenges for seabed mapping, and for spotting small objects at the bottom of the sea. Ole Jacob Lorentzen, PhD candidate at UiO and Researcher at the Norwegian Defence Research Establishment (FFI) is working on improving computer algorithms for processing the imaging from synthetic aperture sonars (SAS) to improve the mapping in rugged terrain. On board, is industrial partner Kongsberg Maritime.

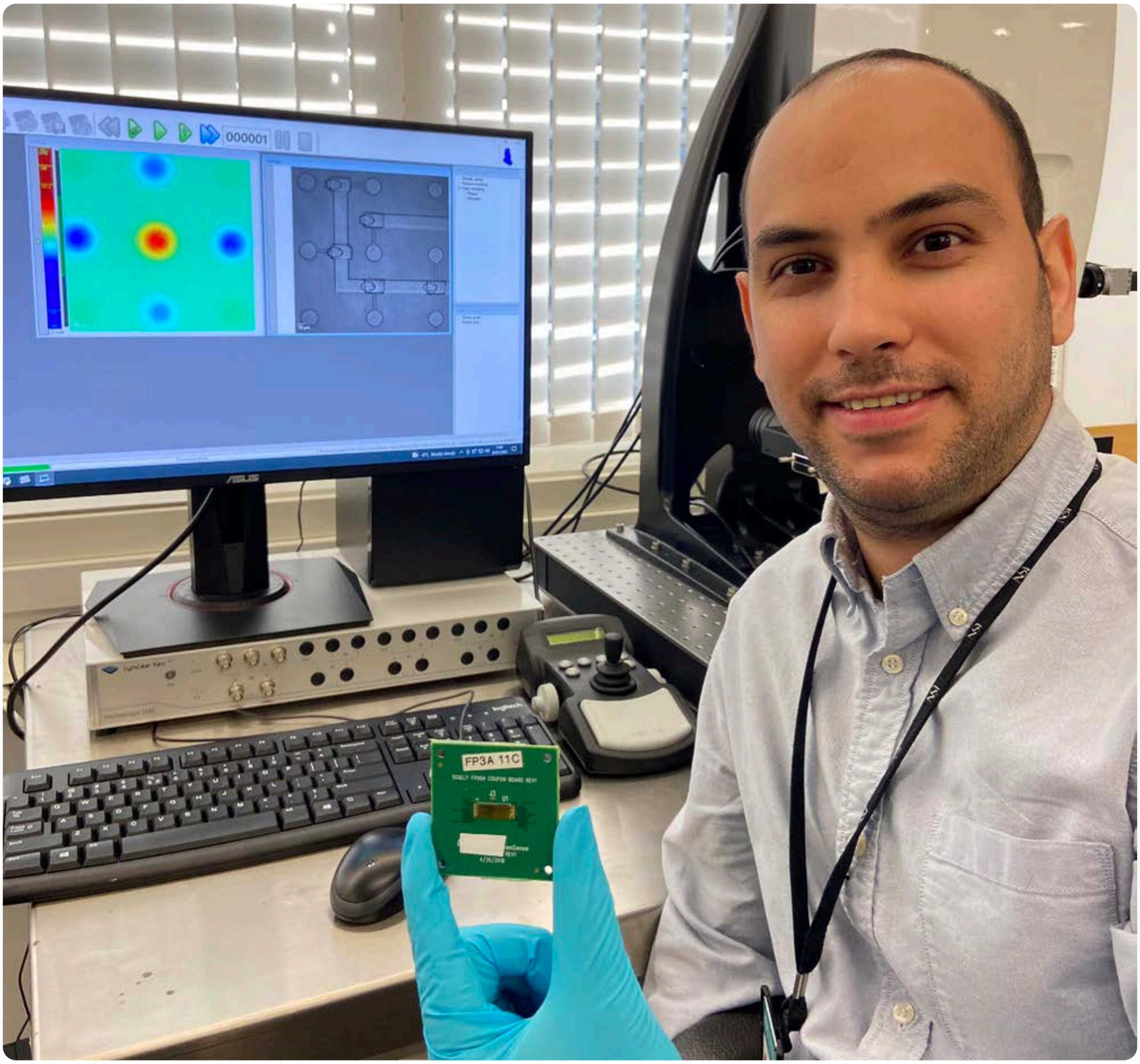
Detecting Issues in the Foetal Heart
Solveig Fadnes, Researcher at NTNU, has started a project with new CIUS partner GEWHUS on bringing blood speckle imaging of the heart from new-borns to imaging the heart whilst still in the womb. The aim is to visualise blood flow patterns in the foetal heart more intuitively and accurately, improving diagnosis at an earlier stage.

Uncovering Stiff or Leaky Heart Valves
Medical doctors and PhD Candidates at NTNU, Torvald Espeland and Erik Andreas Rye Berg are using the latest within medical ultrasound technology to improve the diagnosis of narrow or leaky heart valves. Their research show both the ups and downs of trying out new technology and techniques.

Aiming at Lifelong Partnerships in North America
Siri Ann Nyrnes, Researcher and Paediatric Cardiologist at NTNU/St. Olavs and Professor Lars Hoff, USN, talk about how they benefit from recent INTPART funding awards promoting collaborations with institutions in North America.

ULTRASOUND ON A CHIP

"*When you put something on a chip, you are democratising it because it is going to be cheaper and more accessible*," says Amirfereydoon Mansoori. His PhD work aims to contribute to that.



Amirfereydoon Mansoori in the USN ultrasound transducer lab. Photo: Arian Nowbahari/USN.

Mansoori is a PhD Candidate at CIUS and part of a research group at the University of South-Eastern Norway (USN) working on the transducer design and manufacturing for various applications, where development of alternative transducer technologies is one of the main activities.

"The production process of the current ultrasound transducers tends to be manual, labour-intensive and expensive. My PhD aims to contribute to modelling, design and characterisation of piezoelectric micromachined ultrasonic transducers (PMUTs), which are one alternative to conventional transducers," says Mansoori.

PMUTs are tiny devices. The core of every PMUT is a piezoelectric thin-film, which is typically deposited on a silicon chip based on well-established microelectronic processing techniques. This type of processing offers mass-production that can be much less expensive at large volumes.

The Next Little Thing
PMUTs have been around for some time, but immature processes and low-quality piezoelectric thin-films slowed down the development of high performance PMUTs. "Thanks to remarkable improvements in the piezoelectric thin-film deposition, PMUTs have gained considerable attention in the past 10 years," says Mansoori.

He is in the last year of his PhD and is now concluding his work: "The first part of my project was mostly about identifying the limitations as well as potentials of this new technology through theoretical modelling and simulation. We have also proposed novel design strategies to overcome the limitations and optimise PMUTs for new applications like multi-frequency ultrasound."

Currently he is working on validating and testing the fabricated PMUT prototypes, and there are many potential applications for the technology that he is working on.

"In the medical market, PMUT has the potential where the miniaturisation, cost, being wearable and portable are decisive factors," says Mansoori.

Examples are handheld ultrasound devices for point-of-care diagnostics, ultrasound patches for health monitoring and catheter-based probes for echocardiography.

"In the consumer and automotive markets, PMUTs have already been commercialised as fingerprint sensors providing higher security and time-of-flight sensors to measure distance in robots, drones, and autonomous vehicles. They can also be used as human-machine interface sensors, creating the sense of touch over distance in the metaverse," Mansoori adds. "So, in my opinion, PMUT will be the next 'little thing' in the ultrasound world."

Rewarding Internships Abroad
During his graduate studies, Mansoori has interned with two big companies abroad: "In 2018, I did an internship with one of our industrial collaborators, GE Parallel Design, in France. Later in my PhD, I did a six-month research visit in Milan, Italy with TDK InvenSense."

As an intern with TDK, a leading manufacturer of PMUTs, he worked on the design of next-generation fingerprint sensors. "I designed some PMUT arrays as research prototype fingerprint sensors and have learned a great deal not only about the technology but also about teamwork and problem solving," Mansoori says.

"In the medical market, PMUT has the potential where the miniaturisation, cost, being wearable and portable are decisive factors."

He is very grateful for these opportunities. "Through internships, you can kind of gradually start to transition from being a student to being an engineer working on real-life problems," Mansoori explains.

Also, he appreciates that having had these internships in different countries has made him more flexible.

Learning How to "Kose"
He describes his PhD as a valuable journey with ups and downs.

"It has had multidimensional learning aspects. One, of course, is technical, you become an expert in your field, but one is also about how you manage your time, how you deal with your colleagues, and how you network with other researchers," says Mansoori.

In his spare time, he has mastered the Norwegian art of "kos": "Since I came to Norway, I have started to learn new hobbies and tried to adapt to Norwegian culture, I think now I can "kose" like a Norwegian." When asked for an example, he promptly answers: "One way is to go to nature and relax".

By: Wenche Margrethe Kulmo

ULTRASOUND AND AI IMPROVE SALMON BREEDING AND WELFARE

Ultrasound combined with machine learning provides a new, smart, and more reliable way of estimating the maturation states of salmon with the aim of predicting the optimal timing for egg harvesting.

Ultrasound applied to fish is a new venture in CIUS. Yasin Yari is doing his PhD on ultrasound and machine learning for smart monitoring of maturation states in Atlantic salmon in collaboration with AquaGen, Mowi, and CIUS partner InPhase Solutions. His work builds on that of Dr. Ingun Næve (AquaGen), who developed several methods to screen Atlantic salmon maturation states using state-of-the-art medical ultrasound equipment.

Yasin Yari scanning a fish using ultrasound.

Estimating the Weight of the Ovary
The first task of Yari's PhD project is to measure the length and volume of the fish ovary and estimate its maturation state. The size gives an indication of the weight.

"We need to know the weight of the ovary in the fish. What we can do now is to use ultrasound to get a very good estimation of the weight of the ovary, and having that, we can predict when the fish will be ready for stripping," says Yari. Stripping is the removal of the eggs for further farming.

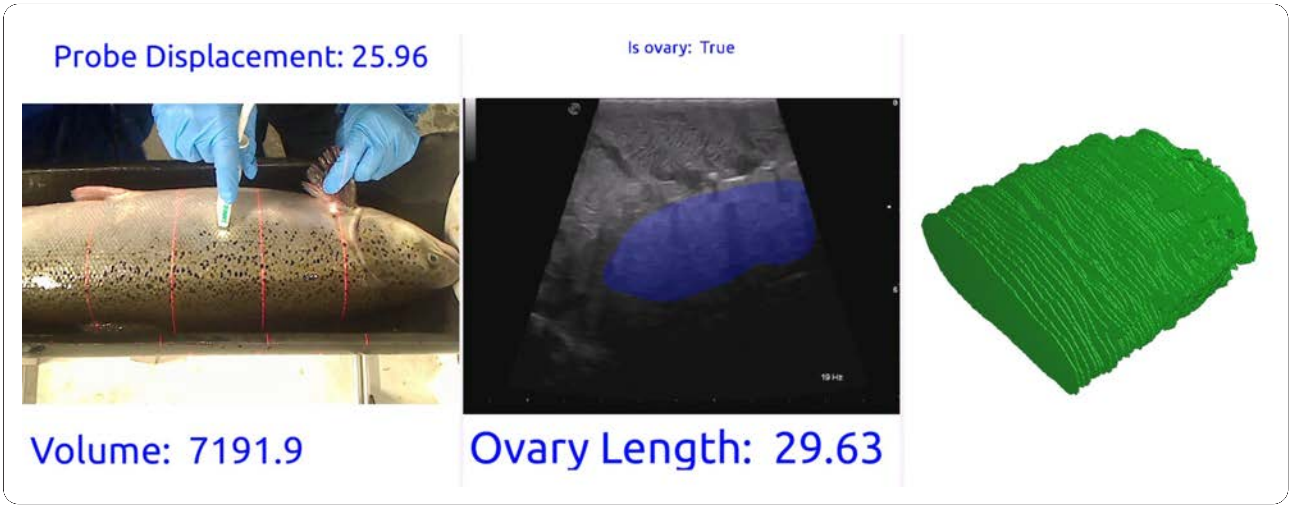
Current methods use an ultrasound probe along with a ruler to measure the length of the ovary manually, but Yari is combining machine learning and ultrasound to automate and improve the accuracy of these methods.

"We are developing a method that can recognise the ovary, measure its length and volume, and estimate the relative weight of the ovary to the fish weight," says Yari.

To use the automatic maturation estimation method more efficiently, there is a need for the automation of ultrasound image acquisition. So, the long-term plan is to scan the fish whilst in water.

"Scanning underwater removes both the need to take fish into the air and the stress associated with the scanning, which benefits fish health and welfare. Moreover, it simplifies the work and reduces the workload for the staff in the production department," Yari points out.

Monitoring the Development of the Eggs
The second task in the PhD project involves smart screening of the development of the eggs. Using ultra-



The figure shows real-time quantification of the ovary for predicting the maturation state: Fish being scanned (left); Real-time segmentation of the ovary in ultrasound (middle); 3D reconstruction of ovary (right). Illustration: Yasin Yari/NTNU.

sound scanning, it is possible to watch as a dark spot appears in the egg, grows bigger and, in the end, almost fully covers the egg. The fish is ready for stripping at this stage, and the belly will now become soft as the fish ovulates.

"Scanning underwater removes both the need to take fish into the air and the stress associated with the scanning, which benefits fish health and welfare."

"At the moment, the procedure is to take the fish out of the tank and check the belly by palpation. The fish is ready for stripping if the belly is soft, meaning the eggs are released. This must be done for each individual," says Yari.

He is optimistic that they can find a way of using the ultrasound image to see if the eggs have been released, avoiding the need for the demanding palpation procedure.

Ultrasound also enables them to see if there is a problem in the ovary. If there is blood in the ovary or eggs are not maturing as expected, the ultrasound image will reveal this, and the fish can be removed from the cage.

Measuring the Fat Content
Finally, the third task is to monitor the fat content of the muscle using ultrasound image analysis.

"The fat content of the fish determines whether the fish will go into the maturation process in that year or if it needs to wait another year to grow and produce more fat before entering the process. The muscle and deep-lying abdominal (visceral) fat content before maturation could perhaps say something about which individuals are more likely to mature, and it can be a selection criterion for broodfish candidates. As maturation progresses, energy stored as fat in muscles and viscera is used in the building of the eggs," explains Yari.

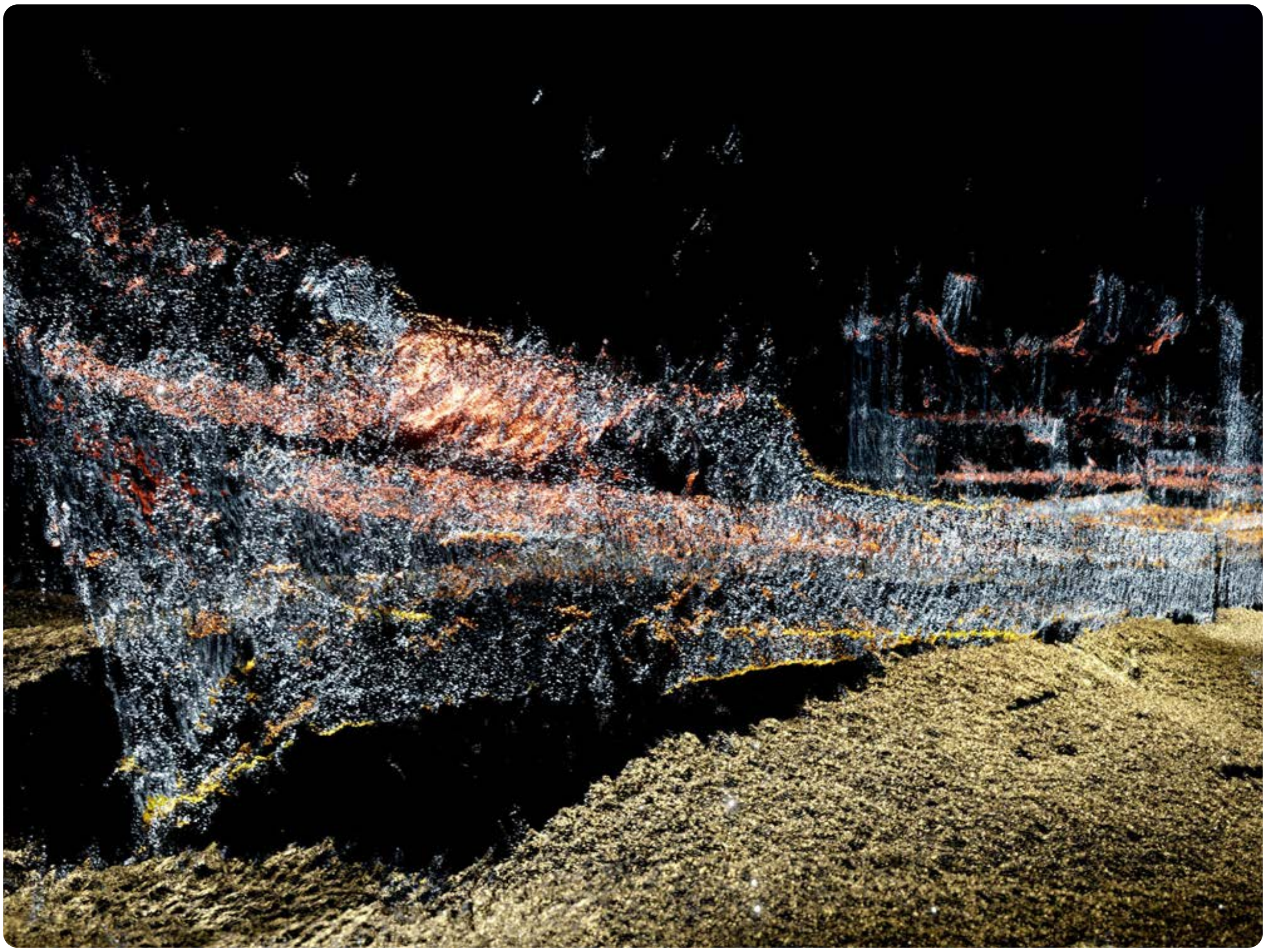
One challenge that Yari faces is the ultrasound probes, which are not customised for this task. Although common standard transducers are good enough to achieve reliable information, the ideal would be to have an ultrasound transducer that is customised for fish scanning.

Yasin Yari started his PhD in December 2020 and is set to complete it towards the end of December 2023. His supervisors are Professor Lasse Løvstakken at CIUS, Dr. Ingun Næve from AquaGen, Dr. Marco Marien Voormolen from InPhase Solutions, together with Dr. Per Helge Bergtun, who is a veterinarian from Mowi and Dr. Svein-Erik Måsøy who is the Director of CIUS.

By: Wenche Margrethe Kulmo

SPOTTING SMALL OBJECTS ON THE SEAFLOOR

A rock the size of a thumb will be visible on the seafloor when PhD candidate Ole Jacob Lorentzen has completed his work on designing the algorithms for images from Kongsberg Maritime's HISAS sonar.



3D Render of SAS Bathymetry Showing a Shipwreck from a World War II Chemical Munitions Dumpsite in the Skagerrak Sea. Picture: Ole Jacob Lorentzen

His PhD work at the Norwegian Defence Research Establishment (FFI) is about improving mapping in rugged terrain: "If the seafloor is relatively flat, we can do this quite well today, but if it is rough, it is much more difficult to make high-quality, high-resolution maps with shipwrecks and other objects," he says.

Lorentzen works on improving the computer-algorithms used for processing the images from synthetic aperture sonars (SAS) making the images more detailed. These sonars combine many acoustic pings to form an image with much higher resolution than conventional sonars. SAS can provide centimetre-resolution over a range of hundreds of metres on the seafloor. The sonar recordings come from the autonomous underwater vehicle HUGIN with the HISAS 1032, developed by FFI and Kongsberg Maritime. The sonar is 100 kilohertz, so this is high-frequency underwater sonar.

"I love to do what I do, and the freedom to try out new things, new methods, to play around with things to get better results."

"The HISAS is an interferometric SAS with two horizontal receiver arrays and a vertical transmit array. This system transmits a wide beam filling a large area on the seafloor with sound," Lorentzen explains.

Better Depth Maps

Lorentzen holds a master's degree in informatics from the University of Oslo. He started his PhD at UiO two years ago and is set to complete it in three years as he also works part-time as a scientist at FFI.

One of the projects he has been working on is a method to extract information about the objects in the image to make an improved depth map. They use two vertically displaced images from the sonar to extract the 3D information:

"It is a black and white image, and I detect data points that should be together. If we do it correctly, it will give us a more correct depth map. It works very well. Although it cannot work in all cases, it improves the result in many cases," Lorentzen says.

Must Get Everything Right

Lorentzen describes programming and data processing as having a million things to keep track of: "There is an infinite number of places where we can make slight improvements, and a few places where we can make bigger improvements. There are many things to be in control of, and it is a huge challenge, actually."

"I love to do what I do, and the freedom to try out new things, new methods, to play around with things to get better results," he adds.

Valuable for a Range of Purposes

High-resolution images of the seafloor are valuable for a variety of purposes. The technology is relatively new, and Lorentzen's work is advancing it further.

"It is a step forward like most research, but also a quite important topic, especially in Norway where we have a lot of marine resources. FFI works closely together with Kongsberg Maritime and the Norwegian navy to improve the technology that is useful for all parties. I also do a lot of work with academic institutions like the universities in Oslo, Bergen, and Trondheim. We go on expeditions and work on data together."

Amazing Images

"I want to collaborate with applied fields and not only be in the signal processing bubble, which is one reason I work with Marine Archaeologist Øyvind Ødegård at NTNU. In Bergen, I work with people in geology," says Lorentzen.

They are developing images from the seafloor at the Mid-Atlantic Ridge, where the continents are moving apart, and there is volcanic activity and fracturing.

"It's not my field, but it's so exciting to learn from the people working on it. And we get amazing images," he says.

By: Wenche Margrethe Kulmo

DETECTING ISSUES IN THE FOETAL HEART

How far can we get in detecting problems in the heart or vessels of the foetus during pregnancy? Using blood speckle tracking CIUS aims to detect problems in the heart and blood vessels of the unborn child with CIUS' new partner, Austrian GE Healthcare Women's Health Ultrasound (GEWHUS).

Researcher Solveig Fadnes, NTNU, and GEWHUS are aiming to improve imaging of the complex cardiovascular blood flow in the foetus. Photo: Kari Williamson/NTNU.

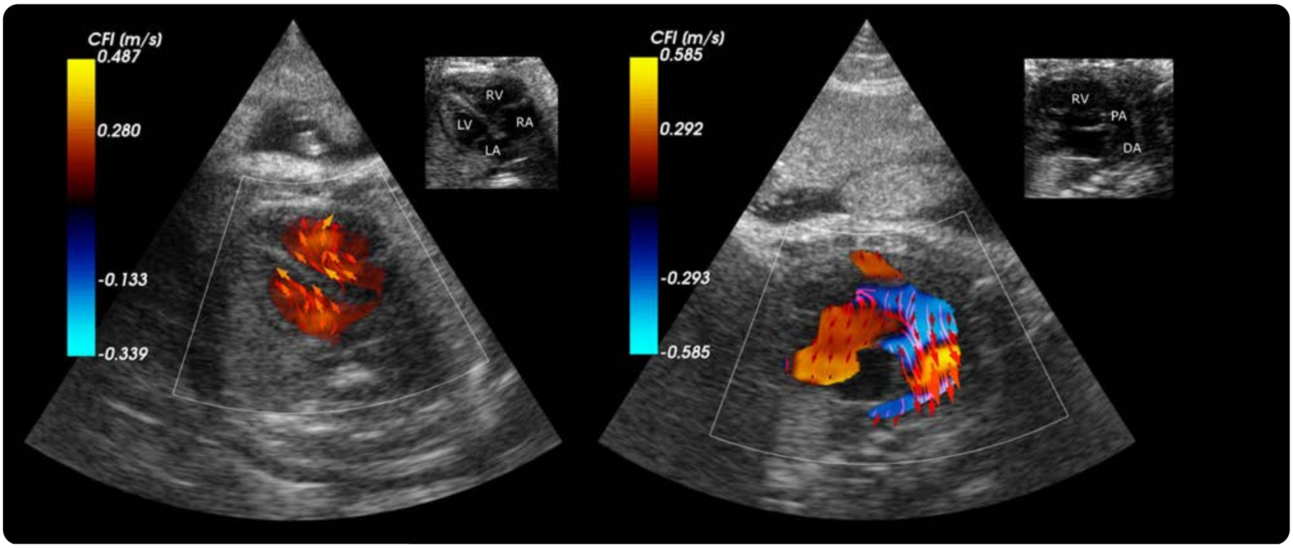
Intuitive Visualisation
The work on flow estimation and visualisation by the ultrasound group at NTNU led to the launch of the BSI (blood speckle imaging) application in the GE Vivid E95 in 2017.

"We can visualise the blood flow patterns in the heart chambers in a more intuitive way using blood speckle tracking. We are not only estimating the velocity component along the ultrasound beam as we do in the colour Doppler mode, but we can get the 2D velocity estimates and visualise the flow streamlines, which is much more intuitive and accurate," says Solveig Fadnes, Researcher at NTNU, CIUS.

As of now, this method is available for probes used for cardiac imaging of children. "The anatomy of the heart and the big vessels is quite complex, so if there's a defect or something is wrong, a more intuitive flow visualisation can help both clinicians and parents understand more," says Fadnes.

Proceeding from Neonatal to Foetal Diagnosis
The team, consisting of people at CIUS and GEWHUS, aims to develop the BSI application for foetal imaging.

The first step is to get the BSI application incorporated into the Voluson scanner, which is GEWHUS ultrasound scanner for women's health. "First of all, we want to transfer our knowledge using the ultrasound probes we are using for paediatric patients. We need a purely technical devel-



Testing foetal imaging using a phased-array paediatric probe. Left: Four-chamber view of the foetal heart. Right: Flow through the ductus arteriosus connecting the pulmonary artery and aorta. Illustration: Solveig Fadnes/NTNU.

opment getting these acquisitions on another type of probe optimising all the technical details," Fadnes explains.

One essential aim of the project is to find out what they can see when the heart is so small. "It would be very good if we could help the clinicians understand the anatomy and physiology to better predict the outcome for the foetus. This is important in order to provide correct counselling for the parents, especially in cases of severe disease where late abortion is considered," says Fadnes.

"It would be very good if we could help the clinicians understand the anatomy and physiology to better predict the outcome for the foetus."

The project is still in the starting block, so it is not yet certain what will be possible. If there's something wrong with an unborn baby's heart, it is important to detect it before birth, as some patients need surgery or intervention soon after birth. In Norway, this treatment is only performed at OUS Rikshospitalet in Oslo, and the pregnant mother needs to be transported there before birth. Fadnes points out that several diseases don't affect foetal life but will become critical after birth, since foetal circulation is very different from that of a delivered baby.

Hoping to Learn More About the Placenta

Imaging of the placenta might be another project. Placenta issues can cause growth restrictions to the foetus but scanning the placenta itself is not part of the ultrasound examinations of pregnant women in Norway today.
"We want to develop acquisitions so that we can better study the placenta. I think we'll have data and images to analyse but it's very difficult to know if it will have a clinical impact. Still, learning more about the physiology of the placenta is also a motivation. Clinicians we have talked to think it's very interesting," says Fadnes.

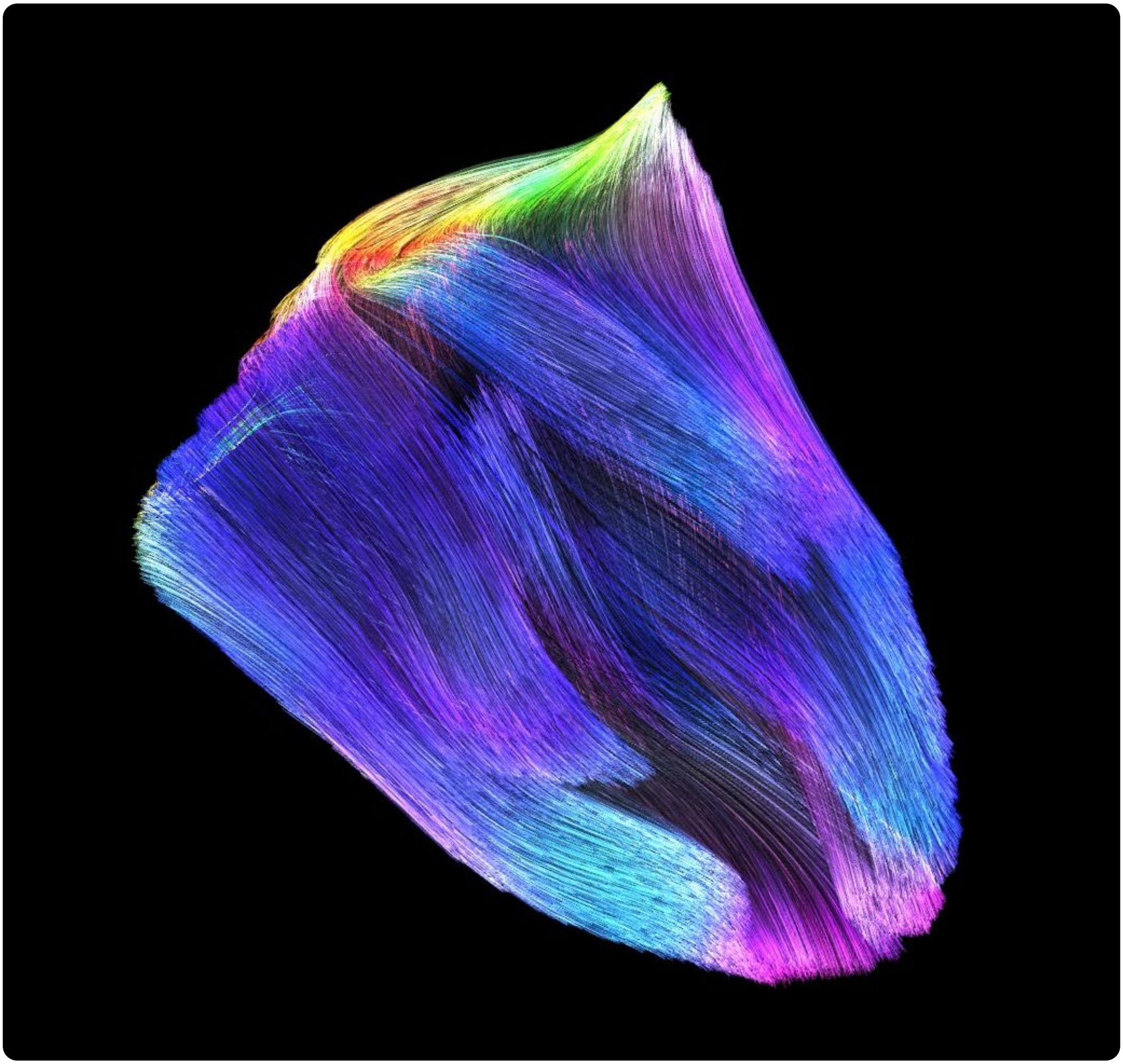
The Team

Three people are being funded directly by CIUS in this project, enabled by the partnership with GEWHUS. Along with Solveig Fadnes is Ingvild Kinn Ekroll on the technical side and Karin Deibele starting to work on a clinical PhD in January 2022, with Paediatric Cardiologist Siri Ann Nyrnes as supervisor. There is close collaboration, with regular meetings and updates from each side.

Solveig Fadnes is happy about this collaboration and how it works. She also appreciates the opportunity to work on a clinical high-end scanner: "It is very motivating with a new clinical partner showing interest in what we have been doing and wanting to implement our methods in their scanner."

By: Wenche Margrethe Kulmo

UNCOVERING STIFF OR LEAKY HEART VALVES



3D ultrasound clutter filter imaging : 3D reconstruction of a natural mechanical wave travelling along a human the left ventricle myocardium. Illustration: Sebastien Salles/NTNU.

Modern ultrasound scanners combined with technological developments at NTNU may improve diagnostics for diseases related to narrow or leaky heart valves. Advanced 3D Doppler and high frame rate imaging makes it possible to visualise cardiac flow and minor movements of the heart's muscular tissue more precisely, according to PhD Candidates Torvald Espeland and Erik Andreas Rye Berg.

Torvald Espeland's research aims to detect increased stiffness of the myocardium (the muscular tissue of the heart) in patients with valvular heart disease. He is optimistic about the results. His colleague Erik Andreas Rye Berg has taken on the challenges of developing better methods to quantify leaks in heart valves.

Visualising the Velocity

Espeland is researching the detection of scar tissue (fibrosis) in the myocardium: "Until now, scar tissue has only been detectable using MRI. Some mechanical waves in the myocardium travel very fast, and the velocity of these waves depends on the stiffness of the myocardium. These waves are now easier to visualise with the newest ultrasound scanner and software developed here at NTNU," explains Espeland.

He has examined 100 patients with a narrow heart valve – aortic stenosis. The patients complete questionnaires, undergo a clinical examination, a walking test and electrocardiograms, and provide blood samples.

"We perform a thorough conventional ultrasound examination on each patient in addition to the newest, more advanced methods that we aim to investigate. All participants undergo a cardiac MRI," says Espeland. They analyse the results to see how well echo performs compared with MRI in detecting scar tissue.

"So far, the new method seems feasible, meaning that it is possible to perform these acquisitions," says Espeland.

Who Needs Surgery or an Intervention?

Patients with aortic stenosis may undergo open-heart surgery or a catheter-based intervention when the heart valve is severely narrowed and they experience symptoms or demonstrate reduced heart function. The typical symptoms will be shortness of breath, chest pains, or fainting during exertion.

"Some patients don't report symptoms at their regular check-ups. When investigating this more, you may discover that they have stopped doing activities they previously enjoyed," says Espeland. One possible reason for this underreporting could be the slow development of the symptoms.

Every year, almost 500 patients at St. Olavs hospital are evaluated for aortic stenosis intervention.

"Lately, a lot of research has focused on examining which patients have worsened prognosis without the traditional symptoms or reduced pumping function. My research adds to that, trying to predict which patients need earlier intervention," says Espeland.

Assessing Leaking Valves

A leaky heart valve causes some of the blood to flow in the wrong direction. If this valvular regurgitation is severe, the patient may need surgery. It is essential to have an exact method to quantify the leak. Currently, the assessment relies on the integration of many methods and parameters, each with its own strengths and weaknesses.

Erik Andreas Rye Berg's research is based on a method developed at NTNU almost 15 years ago, which gave good results but was too complicated to perform in daily clinical life.

"Now we have tried to come up with a simpler method more suited for automated analysis," says Rye Berg.

He explains that while they previously fired many separate ultrasound beams and aggregated them, they now shoot one broad ultrasound beam.

"By firing all the ultrasound elements simultaneously up to 20 000 times per second, we record a cube containing detailed velocity information from the regurgitant jet. This way, we can assess both the volume and area of the regurgitation."

Lab vs. Reality

Initial testing in patients gave promising results. After that, the success rate sank. There are two major problems with the technology: limitations in recording of the highest velocities in some patients, and undesired narrowing of the ultrasound beam. In addition, all the 'noise' created by the human body makes it much harder to use the method in real life than in the lab.

"On paper, this is thrilling. In the lab, the results are good. In the patients, we haven't succeeded yet," Rye Berg concludes.

"Fortunately, I have several projects I am working on in my PhD," he adds. "We are publishing one or two articles on this, because we should tell the world that this is how far we have come, but unfortunately it doesn't work in the patients yet."

As experienced medical doctors, they started their PhD work in 2017 and plan to complete it during 2022, with Svend Aakhus as their supervisor and GE Vingmed Ultrasound as the industrial partner.

By: Wenche Margrethe Kulmo

AIMING AT LIFELONG PARTNERSHIPS IN NORTH AMERICA

Two CIUS-associated projects have received INTPART funding for collaborations with institutions in North America: NeoDoppler and blood speckle tracking (NTNU) with SickKids Hospital in Toronto, Canada, and two exchange agreements (USN) with Stanford University, CA, and the University of Washington, WA, USA.

NeoDoppler: Professor Hans Torp at NTNU invented this technology. A tiny probe fastened to the child's head monitors brain perfusion over time.

Improving Heart and Brain Ultrasound for Children
Paediatric Cardiologist Siri Ann Nyrnes and her team at St. Olavs Hospital and NTNU have been collaborating on blood speckle tracking in the hearts of young children with Section Head Echocardiography Luc Mertens and his team at SickKids Hospital since 2015. Now, with the funding from INTPART, they can continue and expand the collaboration: "An INTPART collaboration is to build a long-lasting relationship with another partner, and we saw this as an excellent opportunity," says Nyrnes.

"An INTPART collaboration is to build a long-lasting relationship with another partner, and we saw this as an excellent opportunity."

Access to Hundreds of Patients
"This collaboration is so valuable for us because here in Trondheim, we have only a few patients in each disease group of serious congenital heart defects, whereas the SickKids Hospital in Toronto has more children in each disease group. It was a great opportunity to be able to include those patients," Nyrnes says.

So far, they have collected around 800 patients in the cardiac project, primarily children under the age of ten years. They have also included ten pregnant women so that they can look at foetal images. The cardiac project is a close collaboration with CIUS partner GE Healthcare.

Non-Invasive Diagnostic Tools
When doing an echocardiographic examination using blood speckle tracking in children, they sit bedside and put a probe on the children's chest. This is a gentler approach since they don't need any contrast agents to visualise detailed flow, and sedation of the child is unnecessary.

"There is a pressing clinical need for developing non-invasive diagnostic tools for visualisation and quantification of cardiovascular function and its impact on brain function and brain perfusion and heart functions in infants and children," says Siri Ann Nyrnes.

INTPART Collaboration is Key to Success
The collaboration with SickKids will also include the NeoDoppler project, which will start at SickKids Hospital in 2022. NeoDoppler monitors the blood flow in the brain.

Nyrnes thinks INTPART is key to succeeding with these projects. SickKids Hospital is renowned for its clinical and research work. Improving education is also a central part of their collaboration, and they have joint PhD students.

Valuable Collaboration with World-Leading Universities
Professor Lars Hoff at the Department of Microsystems at the University of South-Eastern Norway (USN) is looking forward to getting started with the INTPART collaboration with Stanford University near San Francisco, California and the University of Washington in Seattle, WA.

"This collaboration gives us the ability to work and develop courses together with some of the best universities in the world. It allows students to spend a few months at an outstanding research university," Hoff says.

Plans on Hold due to the Pandemic
The pandemic caused a severe delay in the implementation of their plans. In April 2020, they received funding from the Research Council of Norway. Now, they are planning to send the first students in March 2022 and the next in the autumn.

The aim is for the collaborations to become lifelong partnerships, the overall outcome being better products and better researchers.

"We also hope to send researchers and develop some curricula and lectures together," Hoff adds.

International Network
"These are world-leading universities. Stanford lies in the middle of Silicon Valley. The University of Washington is one of the best public universities in USA, with a very strong history in ultrasound and acoustics," Hoff explains.

"For CIUS, this means that the candidates we educate graduate with international experience that prepares them to meet challenges in their future careers. Our field is international and knowing how things are done at world-leading universities is essential. Exchange gives them an international network, which is helpful when you start your career as a researcher or an engineer."

INTPART stands for International Partnerships for Excellent Education, Research and Innovation. It is funded by the Norwegian Ministry of Education and Research (KD), and is administered by the Norwegian Agency for International Cooperation and Quality Enhancement in Higher Education (DIKU) and the Research Council of Norway (RCN).

INTPART was established in 2015.

https://diku.no/programmer/intpart

By: Wenche Margrethe Kulmo

THE BIASED INVENTOR – WHEN AN INNOVATION FAILS

As a researcher in CIUS my job is to develop new knowledge, concepts, and methods to further science and innovation. In doing so, it is easy to be misled, or biased if you will, by one's own ideas. This is a true story.

The Idea
Fellow CIUS colleagues and I, recently came up with a new way of processing ultrasound data which we thought was very smart. It clearly provided better results when compared to state-of-the art methods. We worked hard for almost a year, tested the method in a range of scenarios with large amounts of data. It all matched up; the method was indeed better by all accounts. We could even quantify it, the holy grail of engineering.

In true CIUS spirit, we had regular update meetings with our industrial partner in the project. We discussed the method with their R&D team, showed results, implemented suggestions on improvements from them. The method was also tested, in a simplified way to reduce time, with realistic data from our partner. In the end we all agreed this was indeed promising. A decision was made to create a full pilot of the technology in the partners system for a potential commercial evaluation of the technology.

The Pilot
Our industry partner then devoted internal engineering time for this task, which took several weeks of implementation and testing by experienced engineers and testing personnel. Precious time with a large range of concepts in the pipeline for testing in their product roadmap portfolio. We were all very excited.

When debugging came to an end and the method finally was running, the results were suddenly not at all that promising anymore. We were struggling to see real improvements in the data when testing the method in a realistic use case. This caused several weeks of frantic investigations into why this was the case, with re-runs of the research data, re-evaluation of the software implementation, and new testing. Still, same results: Hard to observe a significant improvement.

The air went out of the balloon. We were all quite disappointed, as we had all hoped this would represent a clear improvement, and we had invested so much time and effort into the project.

The Art of Failing
What happened here? Perhaps not an uncommon experience for many inventors. An idea seems very promising, but does it pass the litmus test? Checking all data in hindsight, the method did improve the data, and it was quantifiable, it was just that the quantitative level was not high enough to make a significant impact in a realistic setting. It also turned out we had taken some shortcuts in our development and testing phases, and not compared it to the optimal implementations of a similar concept our partner already had in their product. That was a mistake.

Also, the improvement came at a high computing requirement cost for our partner, almost overloading the system. As they stated: "There is an improvement, but it's small. With no extra computational cost, this would have been a no brainer, but as of today, this is a no go."

"As a researcher, I was perhaps too optimistic. I truly wanted a method I had been part of developing so much to work that I probably oversold it."

This was a lesson learned for all of us. As a researcher, I was perhaps too optimistic. I truly wanted a method I had been part of developing so much to work that I probably oversold it.

I was the biased inventor.

As a team our checks and balances were perhaps not rigorous enough, we were intoxicated by our own results. We have now learned that by doing more rigorous evaluations at an earlier stage in the project; checking the computational cost in more detail, making sure the implementation we tested was as close as possible to the existing solution, that is not taking short-cuts, we could have foreseen this. With this knowledge, we only become better at our job.

This is the art of failing.

The Grit
We have not given up on the method. This was a first failure, never give up! That is also a very important lesson to learn. We are exploring the potential use of the method for other applications, and they do indeed look promising...

By: Svein-Erik Måsøy,
Industry Liason and Researcher
(Centre Director from 2022)

International Collaboration


Sheffield University, UK
Kings College, London, UK
University of Twente, Netherlands
Århus University, Denmark
Rigshospitalet, København, Denmark
University of Bath, UK
Linköping University, Sverige
Technical University of Denmark, Lyngby, Denmark
Charité Hospital, Berlin, Tyskland
Medical University of Vienna, Austria
Creatis Insa de Lyon, France
GE Parallell design, Sophia Antipolis, France
TDK Invense, Italy
Hohai University, China
University of Rome, Italy
Genth University,Belgium
University of Rennes, France
KU Leuven, Belgium
INSERM, Paris, France
Institute of Cancer Research, London, UK
Ho Chi Minh International University, Vietnam
University of Queensland, Australia

PhD Candidates

Erik Andreas Berg (WP5)
Multimodality and interventional imaging
We refine and validate a computerised algorithm for 3D transthoracic and transoesophageal echocardiographic measures for reconstruction of aortic root morphology. We also work on a semi-automatic computerised algorithm for semi-quantification of aortic and mitral valve regurgitations based on ultrasound data, the clinical value of an algorithm for continuous ultrasound monitoring of LV function during major surgery, and an application for 3D echocardiography of coronary arteries.

Per Kristian Bolstad (WP1)
Transducer design
Central topics of the PhD-project is to develop and investigate new bonding methods for ultrasound transducers, using metal alloys to replace polymers. Single element and arrays will be designed, fabricated and characterised. The stability and robustness of the new structures will be investigated, such as long-time stability, aging, mechanical strength, and behaviour under high temperatures and pressures.

Mikael Estuariwinarno (WP4)
Cement log processing algorithms
Many oil service companies offer ultrasonic pulse-echo cement logging tools of similar design. These tools record similar waveforms, which are then processed to help determine the state of the well. However, different tools typically process waveforms using different algorithms that have never been comprehensively compared with each other. This project will quantitatively compare the performance of these processing algorithms and publish their implementations in an open-source library. Furthermore, it will seek to design a new processing algorithm that improves on existing algorithms by extracting additional information that is known to be contained in the waveforms.

Ali Fatemi (WP2)
Acoustics and beamforming
State-of-the-art echocardiography allows us to correctly diagnose most cardiovascular diseases. An unknown source of clutter, however, hinders the visualisation of the heart in some cases. The aim of this project is to study the cause of this clutter noise in the current echocardiograms and to propose new processing methods to improve the image quality.

Rosa Garone (WP4)
Deep learning for seabed classification in SONAR
Maps of seabed sediments can be obtained by classifying data recorded by sonar systems such as multibeam echosounders (MBES). Although automatic methods for seabed sediments mapping are already in use, map production in geological surveys is still often a manual process. In collaboration with Kongsberg Maritime and NGU, I am studying the applicability and potential of CNNs for the purpose of classifying acoustic seabed imagery into sediment classes. Starting from MBES data, as source dataset, and ground truth data, we aim to help automate the seafloor mapping process in future applications.

Marlene Halvorsrød (WP7)
Clinical feasibility and validation – ischemic heart disease
In our project, we want to find new ultrasound methods to predict who will benefit from revascularisation in heart attacks. We take advantage of ultrasound methods developed in CIUS for detection of fibrosis to decide whether the myocardium is viable. In addition, 1/3 of non-ST-elevation myocardial infarctions have a totally blocked artery and will need treatment immediately. Our aim is to better detect these patients and quantify the myocardial tissue at risk. We use tissue Doppler, strain rate and 3D high frame rate imaging.

Mailys Hau (WP5)
Automated leaflets tracking
Ultrasound analysis is a time-consuming process and is submitted to inter-operator variability. The aim of this PhD is to enhance automated leaflets detection and segmentation by adding a time series point of view. Tracking leaflets on complete acquisition will allow more precise 3D modelling of the valve and follow-up of patients.

Aslak Lykre Holen (WP1)
Transmitters and receivers for ultrasound systems
This project is to develop transmitter and receiver hardware for low power and high integration targeting medical ultrasound. The aim of this project is to study low power adaptive solutions for integrated high voltage ultrasound pulse generators with harmonic suppression, and low power digital hardware beam formers for ultrasound receivers.

Thong Tuan Huyhn (WP1)
Non-ideal effects in transducers
Novel medical ultrasound imaging utilises the nonlinear properties of the tissue. This requires good control of the nonlinear behaviour of the transmit system. The aim of this project is to develop methods to explore and model the nonideal effects in this system, defined as any effect that cannot be described by an impulse response. The ultimate goal is to develop methods to compensate for such effects by shaping the transmit pulses. The project uses our 3D scanning hydrophone measurement tank, connected to a GE Vingmed Ultrasound scanner.

Shivanandan Indimath (WP3)
Identification of influx/efflux in oil and gas boreholes using doppler ultrasound while drilling for early kick detection
Drilling of boreholes in the earth's crust is standard practice for the extraction of oil and gas. The drilling process is an extremely complex and expensive process and the hydraulic pressure balance in the borehole is constantly maintained within certain limits. There are instances when this pressure balance is disturbed due to influx/efflux of formation fluids into/out of the borehole, and this results in "kicks" which can escalate into catastrophic events called "blowouts". Such events pose severe consequences from ecological, economic and safety perspectives. It is the objective of my PhD project to evaluate the applicability of Doppler ultrasound for characterisation of these influx/efflux events while drilling a borehole so that such catastrophic incidents are averted.

Jessica Lage (WP5)
Targeted drug delivery
Acoustic Cluster Therapy (ACT) is found to improve the delivery of drugs and nanoparticles (NPs) to tumours and across the blood-brain barrier. The overall aim of the project is to bring light to the underlying mechanisms ACT, a method that is based on the use of ultrasound in combination with large microbubbles to improve the delivery of NPs to tumour tissue. Of special interest is clarifying the cause and mechanism of the enhanced tissue extravasation and flow through the Extracellular Matrix (ECM), especially on infiltrating ductal adenocarcinoma of the pancreas (PDAC). The project also aims to evaluate the application of ACT mediated delivery in brain diseases, especially on a glioma model. Moreover, we will evaluate the response of the immune system.

Duy Hoang Le (WP1)
New generation cardiovascular ultrasound probe based on a hybrid CMUT-piezoelectric transducer
Motivation of the project is a new type of ultrasound probe which gives higher quality of medical imaging by utilising harmonic imaging technique. The probe consists of a piezoelectric transducer array (as transmitter) and a capacitive micromachined ultrasonic transducer (CMUT) array (as receiver) on the same footprint. The hybrid transducer generates ultrasound beam at frequency f_C and acquires reflected beam at frequency 2 f_C (second harmonic). The advantages of the new technology are lower reverberation noise and improved axial and lateral resolution.

Malgorzata Magelssen (WP6)
Diagnostic accuracy of handheld ultrasound
Significant efforts are being made to improve the diagnostic accuracy of handheld ultrasound devices (HUDs). This can enhance the art of clinical examination by revealing disease at an earlier stage and help to better identify patients in need of specialised care. The focus of our scientific work is to study the feasibility, accuracy and reliability of HUDs when used by less experienced healthcare professionals such as general practitioners (GPs) and specialised nurses after a period of focused training. We want to evaluate the usefulness of using HUDs as a supplement to clinical diagnostics in patients with suspected heart failure. Further, we want to evaluate the use of automatic analysis of heart function and telemedical support from cardiologists.

Amirfereydoon Mansoori (WP1)
Wideband solutions for Piezoelectric MEMS Ultrasonic Transducers (PMUTs)
Piezoelectric MEMS Ultrasonic Transducers (PMUTs) are promising alternatives to conventional bulk piezoelectric transducers, particularly in applications where miniaturisation, cost, ease of fabrication and integration to the front-end circuitry are of critical importance. Unlike its capacitive counterpart (CMUT), PMUT does not require a DC bias voltage and operates linearly, however the performance of conventional PMUTs have been limited by their narrow bandwidth. The aim of this project is to first identify the theoretical as well as practical limits of PMUTs and then propose novel solutions to enhance the bandwidth of such devices enabling new ultrasonic imaging applications.

Wadi Mawad (WP7)
Cardiac blood flow and blood speckle tracking

The use of high frame rate ultrasound and blood speckle tracking allows the visualisation of cardiac blood flow patterns and quantification of flow characteristics such as vorticity and energy losses. Changes in flow characteristics are thought to precede overt cardiac remodelling which makes them potential early biomarkers of adverse cardiac remodelling. This project focuses on the application of this imaging technology to multiple congenital cardiac conditions in children to assess its feasibility, reproducibility and to demonstrate differences in flow characteristics.

Simen Hammervold Midtbø (WP4)
Crack detection

Cracks and defects in oil- and gas pipelines are a major concern to operators across the globe today. NDT Global is a company that is developing a tool that can detect and quantify the severity of the cracks, using ultrasound and tomography methods. By exciting and recording the resonances in the pipewalls using an array of ultrasound transmitters and receivers, tomography methods can be used to detect irregularities within the pipewall. The challenge, however, lies in differentiating actual cracks from more general irregularities, such as corrosion, within the pipe. It is our objective to contribute to this task by optimising an inverse tomography technique that combines theory and measurement, while simultaneously increasing knowledge on how waves interact with cracks to improve analysis results.

Olivia Mirea (WP1)
In-probe receivers for medical ultrasound systems

The purpose of this research is to improve the quality of ultrasound heart imaging by developing new integrated in-probe electronics using dual frequency hybrid CMUT technology. Different topologies of LNA (low noise amplifier), TGC (time gain compensation amplifier) and ADC (analogue to digital converter) will be studied/compared, the aim of the project being to find new ideas of improving the current state-of-the-art of the circuits.

Danial (Mohammad) Mohajery (WP3)
Mechanical wave propagation in LV

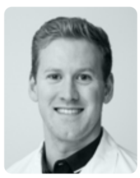
Underlying pathologies and deficiencies of the heart often lead to characteristics changes of the cardiac tissue. Knowing that mechanical wave propagation in the myocardium is connected to tissue properties, I aim to study naturally produced waves during a cardiac cycle as a tool for pathology diagnosis. Combining high-frame-rate ultrasound volumes with AI-based processing, I plan to evaluate wave velocity and to construct a 3D velocity map of the left ventricle. In addition, in collaboration with medical PhDs, I conduct large cohort studies to verify the validity of my tool.

David Pasdeloup (WP4)
Image analyses

With the availability of portable ultrasound devices, the number of examinations carried out by non-expert users will increase. The aim of the project is to use state-of-the-art machine learning to develop tools that aid the non-expert user when acquiring images, performing image measurements, and for proposing an initial diagnosis. All steps in the echocardiography workflow can benefit from these tools. Challenges in image acquisition will initially be approached by developing a probe guidance system. Further focus will be placed on automatic interpretation of ultrasound images.

Josh Hoi Yi Siu (WP1)
High temperature transducers for applications in the oil and gas industry

Non-destructive testing and monitoring in the oil and gas industry in some cases require the use of transducers that can operate at very high temperatures, e.g., above 500°C. High temperature piezoelectric ultrasound transducers have been a prime candidate in such applications, due to their simplicity and ease of integration. The goal of this project is to investigate, develop, fabricate, and characterise piezoelectric transducer elements for use at such high temperatures. Evaluation of long-term stability and reliability are central parts of the project.



Andreas Sørbrøden Talberg (WP2)
Acoustics and beamforming

The focus is on using ultrasonic non-destructive testing methods in applications related to the oil & gas industry. Current work is being conducted with WP3 to combine the knowledge related to the propagation of waves in solids and the use of Doppler methods to inspect flow behind a solid layer through numerical and experimental work.

Anders Emil Vrålstad (WP2)
AI beamforming
In collaboration with GE Healthcare Women's Health Ultrasound, I work on improving image quality in medical ultrasound using artificial intelligence (AI). The aim is to correct the delay model in the beamformer by estimating the speed of sound of the imaging tissue. My research is based on image quality metrics, advanced beamforming techniques and machine learning. Improvement in image quality will hopefully result in more precise medical diagnosis and faster ultrasound examinations.

Magnus Wangensteen (WP2)
Increased sensitivity and detailed diagnosis of corroded oil and gas pipes using ultrasound
Some of the challenges with the current corrosion monitoring is inexact sound speed temperature compensation and undetermined pitting developments on the inner pipe wall. The objective of this project is to investigate improved transducer technology and algorithms to address these challenges. This may be achieved by using annular arrays for detection of pitting or by taking advantage of guided waves for advanced diagnosis between sensors.

Sigurd Vangen Wifstad (WP3)
3D Doppler and Machine Learning to evaluate mitral valve disease
Mitral valve disease is one of the most common heart diseases, with an estimated prevalence of 2-3% globally. Diagnosis of mitral valve disease is commonly performed with ultrasound, but providing accurate quantitative measures is difficult because of physical and technological limitations. In this project we wish to improve the quantitative metrics for valve disease severity grading to aid doctors provide correct treatment to patients. We will explore the use of 3D Doppler ultrasound and machine learning to measure regurgitant orifice areas and flow volumes.

Yasin Yari (WP4)
Machine learning and ultrasound to predict Atlantic salmon maturation
The goal of my PhD project is to research and develop state-of-the-art machine learning methods for determining various important maturation states of Atlantic salmon with the aim of predicting the optimal timing of egg stripping for breeding purposes. This includes performing tasks like real-time segmentation and classification in the ultrasound image of the fish ovary in combination with using peripheral sensors for having an autonomous prediction. This may result in a set of methods that can be applied to the daily operations of the Atlantic salmon farming companies.

Andreas Østvik (WP4)
Image processing, analysis and visualisation
The goal of my PhD project is to utilise and further develop machine learning methods to improve state-of-the-art solutions in the field of ultrasound image analysis and visualisation. More specifically, research will be conducted on tasks such as classification of standard plane views in echocardiography, cardiac landmark detection, and heart chamber segmentation in ultrasound images.

Postdocs

Stefano Fiorentini (WP3)
Valve insufficiency quantification
My main research field is the quantification and imaging of blood flow using Doppler ultrasound. The aim of my current research project is to develop new methods and acquisition sequences to quantify the severity of mitral and aortic valve insufficiency. We have developed a method that combines 3D ultrasound technology and high frame-rate acquisitions to measure the regurgitant volume, an important parameter in the assessment of valve insufficiency. The method passed the technical validation stage and is currently undergoing preliminary clinical validation.

Jahn Frederik Grue (WP6)
Improved diagnostics of cardiotoxicity and valvular disease
Novel methods based on artificial intelligence and machine learning can improve analysis in echocardiography. My research is on using such methods for more sensitive detection of heart disease. In this project, the focus is on cardiotoxicity caused by chemotherapy for breast cancer, mitral regurgitation, and aortic stenosis. The aim is to develop and validate methods for automatic echocardiographic detection and grading of these diseases.

Hoai An Pham (WP5)
Interventional ultrasound
The aim of the postdoc project is to solve some of the challenges in the development of the interventional cardiology ultrasound, such as detecting probe movement from 3D TEE data, dynamic movement compensation, and dynamic tracking of anatomic landmarks by using ultrasound-to-ultrasound global rigid motion registration. The developed tools will be implemented in a software plugin provided by GE, and then in real-time on a GE scanner for the local clinical team to evaluate the developed tools.

Ole Marius Hoel Rindal (WP2)
Advanced beamforming
My postdoc research is on beamforming for medical ultrasound imaging, more specifically on advanced beamforming techniques to improve image quality. Improved image quality will lead to images that are easier to interpret for the clinicians, resulting in more correct and precise medical diagnosis. Part of my research is on the metrics and the development of more relevant and useful metrics to evaluate the image quality improvements. Most of my work is centred around the development and maintenance of the UltraSound ToolBox (http://www.USTB.no)

Erik Smistad (WP4 and WP5)
Image processing, analysis and visualisation
I am primarily working on image segmentation and exploring new developments in the field of machine learning and neural networks. The work has so far been on classification of images, as well as identifying structures, such as blood vessels and the left ventricle. I have also developed software tools for easy annotation of ultrasound image data (Annotationweb), and tools for processing ultrasound images with a trained neural network in real-time.

Erlend Viggen (WP4)
Ultrasonic petroleum well logging
The integrity of a petroleum well can be evaluated with the help of measurements in the well, including ultrasonic ones. Equinor has released a large set of well measurement data to CIUS, and I am working on developing techniques to draw new information about the well status from this data. The aim is to provide more certainty about the status of the well, so that expensive operations such as plug-and-abandonment can be carried out in more cost-effective ways.

Morten Wigen (WP3)
2D and 3D echocardiography
My postdoc project topics are related to measurements of both tissue and flow properties in the heart, using 2D and 3D echocardiography. The enabling technology for both projects is high frame-rate imaging, which is sensitive to rapid changes needed to capture mechanical waves travelling in the heart walls and the blood speckle movement in the ventricles. The methods used for the projects have undergone technical validation and are currently in a phase of clinical validation. For this I'm working together with clinicians who are using software where the methods are implemented. I am also working on technological novelties related to the processing of ultrasound signals to further improve our measurements, and to the new parameters that can be extracted from them.

The Voluson E10 from GE Healthcare. Image: GE Healthcare Women's Health Ultrasound

Scientific Personnel

Tore Bjåstad
Scientific programmer
The main purpose of Bjåstad's work is to accelerate the process of getting new methods and algorithms into a product. Primarily, the product will be a GE Vingmed Ultrasound scanner intended for cardiovascular imaging. This work will typically involve further development of scanner code to make it capable of executing new methods in real-time, or to collect data for offline processing, or in some cases just assistance in how to set up and use existing functionality of the scanner.

Solveig Fadnes
Researcher
Fadnes is a researcher at NTNU with background in applied physics. She has worked with research within medical ultrasound technology since 2010. Research interests include cardiac blood flow imaging, especially for foetal and paediatric applications.

Martijn Frijlink
Associate Professor
The Department of Micro- and Nanosystem Technology (USN) are developing and investigating different aspects of ultrasound transducers for applications in both medical, maritime, and industrial fields. With Frijlink's background in different medical and nonmedical ultrasound applications, and having experience from the field of medical transducer design and manufacturing, his contribution mainly consists of supporting different ultrasound transducer related projects.

Bjørnar Grenne
Researcher
Grenne is a researcher at NTNU and a Cardiologist at St. Olavs Hospital. His main research areas are advanced echocardiography, valvular disease, coronary artery disease and echocardiography in valve interventions.

Espen Holte
Researcher
Holte is a researcher and Section head, Echocardiography at the Clinic of Cardiology, St. Olavs hospital. His main research areas are advanced echocardiography, machine learning, valvular disease, and coronary artery disease.

Alan Hunter
Associate Professor
Dr Alan Hunter is a researcher and engineering lecturer at the University of Bath, UK. His research interests are in underwater remote sensing using acoustics and autonomous systems, and he is a specialist in high resolution synthetic aperture SONAR imaging. Dr Hunter has been an Adjunct associate professor at the Department of Informatics at the University of Oslo (UiO) since 2017.

Tonni Franke Johansen
Researcher
Tonni Franke Johansen is a researcher at SINTEF and NTNU. His research interests are simulation and instrumentation for ultrasonic measurement systems. He contributes to research and supervision at USN with piezoelectric transducers, and at NTNU with wave propagation in layered media.

Gabriel Hanssen Kiss
Associate Professor
Hanssen Kiss works on fast registration and fusion tools for cardiac applications in order to identify and characterise the dynamics and function of cardiac structures based on multi-modal image data. In addition, he is also involved with augmented reality visualisation techniques to be used in the echocardiographic lab under image acquisition.

Spiros Kotopoulis
Associate Professor
Dr Kotopoulis' research focuses on the use of ultrasound to enhance targeted drug-delivery with an aim of increasing therapeutic benefit. Dr Kotopoulis' research ranges from understanding the microbubble-cell-ultrasound interactions to developing novel ultrasound transducers that accelerate and improve pre-clinical research and improve clinical translation. He is also involved with image-based data analysis and validation techniques.

Luc Mertens
Professor
Luc Mertens is Section head, Echocardiography at the Labatt Family Heart Centre, Hospital for Sick Children in Toronto, Canada. Dr Mertens' research interests focus on using new echocardiographic techniques to study the heart function in children. He is a Guest researcher at CIUS, collaborating on applications of high frame-rate ultrasound in children with heart disease.

Ole Christian Mjølstad
Researcher
Mjølstad has worked with the development of pocket-sized ultrasound technology since 2009, trying to improve physical examination and to increase diagnostic precision. Mjølstad and his colleagues work continuously to establish the position of pocket-sized ultrasound in daily clinical care. An important part is the development and clinical evaluation of applications that increase the usability among non-experts.

Sebastien Salles
Researcher
Sébastien Salles is a researcher at the laboratory of medical imaging (LIB) in Paris. He is currently developing new echocardiography techniques to improve the detection of cardiovascular diseases. His research focuses on creating and developing novel methods for tissue characterisation thanks to the propagation of mechanical waves produced by the Heart itself.

Anders Thorstensen
Researcher
Thorstensen and his colleagues aim to evaluate the diagnostic accuracy of post systolic foreshortening for direct echocardiographic quantification of myocardial infarct size, using LE-MRI as the reference method. The areas of post systolic of foreshortening are likely to benefit from early revascularisation in patients with acute myocardial infarction.

Svein Arne Aase
Lead Engineer
Svein Arne Aase and a small group of GE Vingmed employees are co-located with NTNU's ultrasound researchers. Aase is Vingmed's CIUS contact for research projects within Doppler and Deep Learning. Within Vingmed, he is leading a team integrating Deep Learning models into the ultrasound scanners. Their goal is to improve accuracy, reproducibility, and efficiency by supporting human intelligence with automatic tools.

Researchers with External Financing in CIUS-projects

Postdoctoral Researchers
Anna Karlberg, NTNU
Sofie Snipstad, NTNU

PhD Candidates
Håvard Kjellmo Arnestad, UiO
Annichen Søyland Daae, NTNU
Caroline Einen, NTNU
Henrik Fon, NTNU
Gabor Gereb, UiO
Thomas Grønli, NTNU
Anna Hjort Hanssen, NTNU
Margrete Haram, NTNU, St. Olavs hospital
Jieyu Hu, NTNU
Ole Jacob Lorenzen, UiO/FFI
Melina Mühlenpfordt, NTNU
John Nyberg, NTNU
Sindre Hellum Olaisen, NTNU
Marieke Olsman, NTNU
Håkon Pettersen, NTNU
Sebastian Price, NTNU
Ellen Sagaas Røed, USN
Ivar Salte, SSHF
Lars Saxhaug, NTNU
Sigbjørn Sæbø, NTNU
Kristian Sørensen, NTNU
Sander Bøe Thygesen, UiO
Silje Kjærnes Øen, NTNU

CIUS Faculty

Svend Aakhus, Professor, NTNU
Knut E. Aasmundtveit, Professor, USN
Andreas Austeng, Professor, UiO
Jørgen Avdal, Research Scientist, SINTEF
Sigrid Berg, Research Scientist, SINTEF
David Bouget, Research Scientist, SINTEF
Håvard Dalen, Associate Professor, NTNU
Live Eikenes, Associate Professor, NTNU
Ingvild Kinn Ekroll, Researcher, NTNU
Roy Edgar Hansen, Professor II, FFI/UiO
Rune Hansen, Senior Research Scientist, SINTEF
Tung Mahn, Associate Professor, USN
Siri Ann Nyrnes, Reasearcher, NTNU
Ingerid Reinertsen, Senior Research Scientist, SINTEF
Erik Smistad, Research Scientist, SINTEF
Ole Vegard Solberg,Senior Research Scientist, SINTEF
Annemieke van Wamel, Researcher, NTNU
Rune Wiseth, Professor, St. Olav/NTNU
Andreas Østvik, Research Scientist, SINTEF
Andreas Åslund, Researcher, SINTEF

The CIUS Fall Conference 2021 was the first physical (and hybrid!) conference since 2019, and saw a record number of attendees. Photos: Kari Williamson/NTNU

Dissemination, Media Coverage and Outreach

CIUS acknowledges the importance of communicating our research to the public, and in 2021, we increased our efforts in social media.

Looking back to the annual report of 2020, it was full of hope for more physical meetings and other dissemination possibilities – but alas... Covid decided otherwise apart from the brief spell of freedom during the autumn – which incidentally ended during our first physical conference since 2019! No-one present will forget the nail-biting suspense during the conference dinner which coincided with the government's press conference announcing a return to partial lock-down. Luckily with 24-hour warning, so the 90-or so physical attendants could return for day 2!

As it happens, the conference had the highest total number of attendees (physical and digital) since the first CIUS conference in 2016. In addition to stimulating presentations from new and old projects in CIUS, the conference saw the stepping down of CIUS Director Asta Håberg and the handover of the baton to Industry Liaison Svein-Erik Måsøy. In her farewell speech, Asta Håberg said: "It has been very interesting for me because I come from MRI and cognition. I have learnt a lot, I am very happy that Svein-Erik is taking over, because this is really his baby. I think now that I have had the early parts of the upbringing, he can take it to the teenage years and into adulthood, and then we will hopefully have a new baby, a new SFI maybe, in a couple of years."

Other highlights of the year, include the opening of the exhibition "Life and Death" at Teknisk Museum in Oslo. The exhibition includes equipment from the very start of the ultrasound research and development in Norway, up to a Vscan donated by GE Vingmed Ultrasound. It was great fun to assist Teknisk Museum and NTNU's Medisinsk Museum in collecting equipment and information!

Our efforts on social media platforms are starting to pay off. We have never had so much response on individual posts as we saw in 2021. A positive side-effect of the Covid-19 pandemic is that we have been able to share links to upcoming PhD defences, and these posts have done very well – especially on LinkedIn. We have continued to share new academic articles, open positions, and general news from CIUS and the CIUS family. This is something we will continue to focus on in 2022.

When it comes to blogging, we have had a bit of a dry well situation. Our ambition to share more posts at Forskning.no turned out to be – well, a bit too ambitious considering so many of us work, live, and communicate in English. We have therefore taken steps setting up our own: www.ntnu.no/blogger/cius,. We will still evaluate new blog posts for Forskning.no, but we hope to include more of our fresh researchers and staff in blogging by lowering the (language) barrier.

For 2022 we hope to see more blog posts, and again be able to join the National Science Week (Forskningsdagene), and we look forward to physical conferences in Åsgårdstrand in Vestfold and Telemark in May and Trondheim in the autumn.

CIUS PEOPLE TO FOLLOW

BLOGS
ntnu.no/blogger/cius
erlend-viggen.no
www.eriksmistad.no

TWITTER
@olemjolstad (Ole Christian Mjølstad)
@ErlendViggen (Erlend Viggen)
@alfonso_molares (Alfonso Molares)
@larshoff1 (Lars Hoff)
@annichendaae (Annichen Søyland Daae)
@strain_rate (Asbjørn Støylen)
@ErikSmistad (Erik Smistad)
@DrAlanHunter (Alan Hunter)
@andtal1 (Andreas S. Talberg)
@bgrenne (Bjørnar Grenne)
@load_dependent (Lars Mølgaard Saxhaug)
@Sverre_Holm (Sverre Holm)

CIUS IN SOCIAL MEDIA 2021

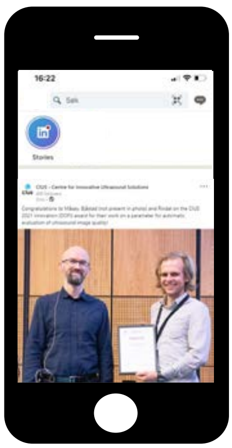
@ **CIUS_NTNU**
208 followers
37 tweets

@ **CIUS**
352 followers
36 updates

@ **NTNUhelse**
8311 followers
7 updates

TOP CIUS POSTS 2021

7 LIKES
17 CLICKS
1604 IMPRESSIONS
3 SHARES



77 LIKES
80 CLICKS
2705 IMPRESSIONS
2 SHARES

153 LIKES
5644 REACH
3 ENGAGEMENTS
9 SHARES

Exact Therapeutics fikk avtale med GE Healthcare

Bioteknologiselskapet Exact Therapeutics har inngått et samarbeid med GE Healthcare for å utvikle en ultralydsonde som skal brukes i studier hvor metoden Acoustic Cluster Therapy brukes blant flere sykdomstilfeller. (DN Investor)

Kompetansen har gradvis forsvunnet fra distriktene. Nå vil folk tilbake

Flere akademikere kunne tenke seg til distriktene, likevel bor kun én av 20 over 90 minutter unna en by.

I dag bor 85 prosent av Norges akademikere innen 30 minutter fra en by. Nå oppgir de at de vil flytte til distriktene.

Nå får de første pasientene forskernes nye kreftkur

Investorene og teamet i Cimon Medical.

Slik hentet gründerne 60 millioner ved å overlate investorjakten til investoren

Samarbeider med amerikansk gigant

Sammen med GE Healthcare skal EXACT Therapeutics utvikle en innovativ sonde til bruk i kommende studier.

Publisert 20. jan. 2021 kl. 11.42

FORBEREDER NY FASE: EXACT Therapeutics og adm. direktør Rafiq Hasan.

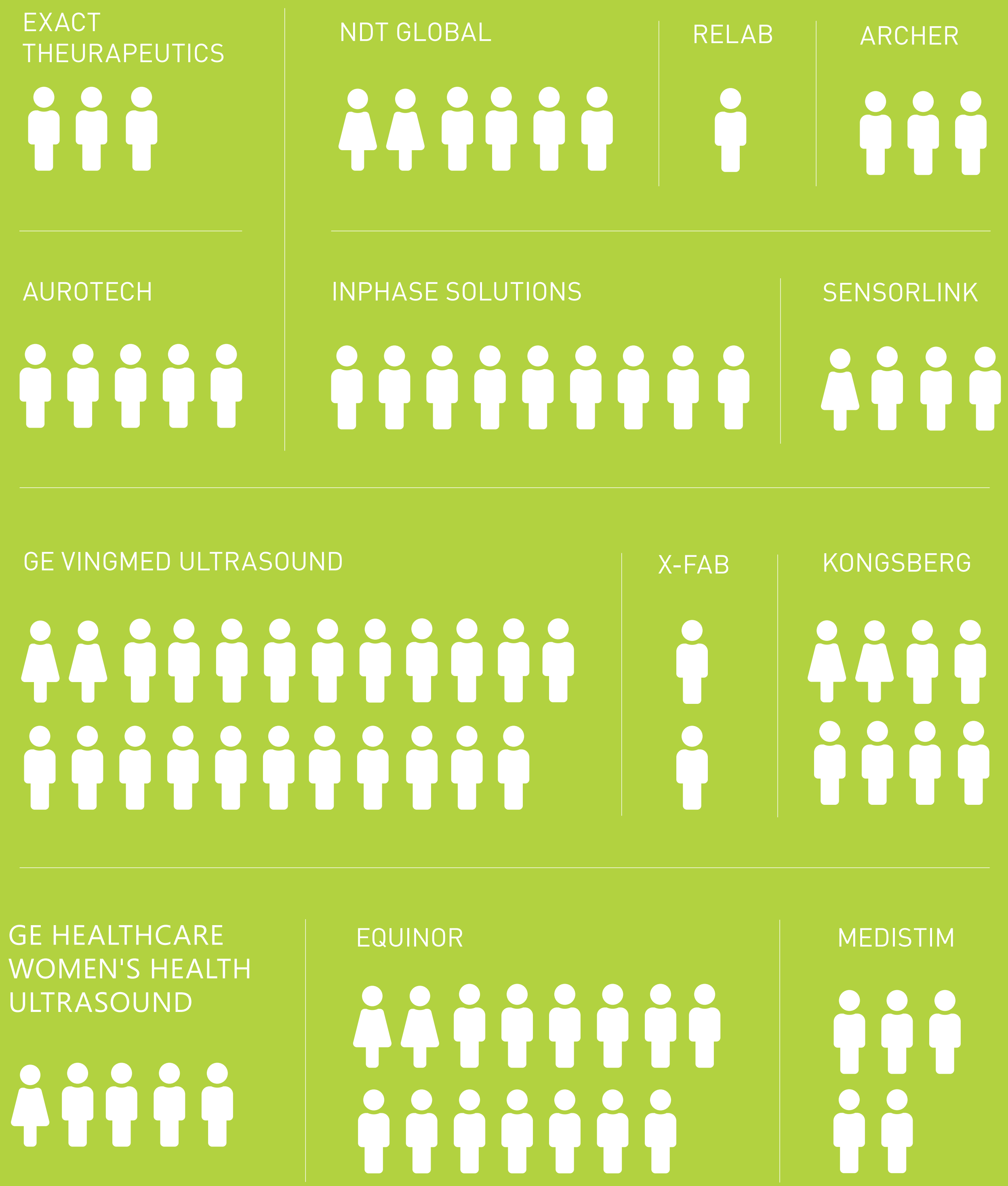
TITLE	MEDIUM
Slik hentet gründerne 60 millioner ved å overlate investorjakten til investoren	Shifter.no
Exact Therapeutics inngår avtale med GE Healthcare	Dagens Næringsliv
Finanssjefen ferdig i EXACT	Finansavisen.no
What's Next for Computer Vision Systems and Data Analysis?	YouTube/SPE
Technoport Podcast #6 - Asta Håberg	Podchaser.com
John Fredriksens Aeternum gjør storkjøp i Medistim - kjøper aksjer for nesten en halv milliard	Dn.no
Hjertelig nyhet fra hortensbedriften: - Nå blir livreddende teknologi mer tilgjengelig!	Gjengangeren+
Cimon Medical venter på CE-godkjennelsen	Kapital
Kompetansen har gradvis forsvunnet fra distriktene. Nå vil folk tilbake	MN24
Kompetansen har gradvis forsvunnet fra distriktene. Nå vil folk tilbake	Adressa
A Norwegian journey in audio and acoustics	NNNN blog
Exhibition “Life and Death” – with equipment from the CIUS family	Teknisk Museum, Oslo
Open source processing of ultrasound images with the USTB	CIUS Blog
GE Healthcare Women’s Health Ultrasound new CIUS partner	CIUS Blog
Nå får de første pasientene forskernes nye kreftkur	Sintef.no
NTNU svarer eks-Google-sjef: Relevant samfunnsbidrag	Khrono.no
CIUS Fall Conference 2021	CIUS Blog

Innovation Prize

Researcher and Industry liason officer Svein-Erik Måsøy, Postdoc Ole Marius Hoel Rindal, and Scientific Programmer Tore Grüner Bjåstad (not present for photo), received the 2021 CIUS Declaration of Innovation (DOFI) Prize of NOK 25 000, for their work on a parameter for automatic evaluation of ultrasound image quality.

Photo: Kari Williamson/NTNU

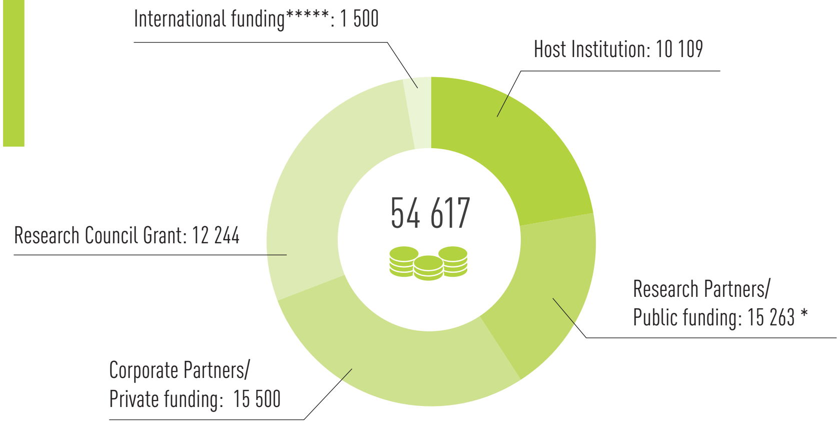
Industry Partner R&D Staff



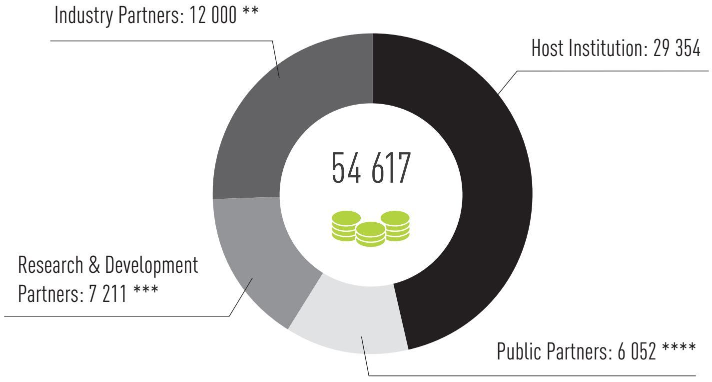
Assistant Director Espen Rostrup Nastad at the Norwegian Directorate of Health opened the exhibition "Life and Death", which contains items from CIUS, at Teknisk Museum in Oslo. Photo: Teknisk Museum

Annual Accounts for 2021

FUNDING
(in 1000 NOK)



COSTS
(in 1000 NOK)



*SINTEF, University of Oslo, University of South-Eastern Norway, Helse Midt-Norge RHF, St Olavs University Hospital HF, Nord-Trøndelag Hospital Trust, Levanger municipality, Verdal municipality

**Equinor, GE Vingmed Ultrasound AS, Archer Bergen Technology Center AS, Sensorlink Subsea AS, Exact Therapeutics AS, InPhase Solutions AS, Kongsberg Maritime AS, NDT Global, Aurotech Ultrasound AS, X-Fab Semiconductor Foundries AG, Medistim ASA

*** SINTEF, University of Oslo, University of South-Eastern Norway

****St Olavs University Hospital HF, Nord-Trøndelag Hospital Trust, Levanger municipality, Verdal municipality

*****GE Healthcare Women's Health Ultrasound (GEWHUS)

Journal Articles and Conference Proceedings - CIUS

AUTHOR/AUTHORS	TITLE	JOURNAL
Nyman M, Molaug IC, Næss AM, Espeland T, Loennechen JP, Mjølstad OC	Implantasjon av hjertestartere ved St. Olavs hospital 2006–15	Tidsskriftet Den norske legeforening
Mawad W, Dutil N, Thakur V	Unique foetal diagnosis of aorto-pulmonary collaterals in right atrial isomerism	Cardiology in the Young
Jarmund AH, Ødegård SS, Torp H, Nyrnes SA	Effects of tilt on cerebral hemodynamics measured by NeoDoppler in healthy neonates	Pediatric research
Godin OA, Deal TJ, Dong H	Physics-based characterization of soft marine sediments using vector sensors	The Journal of the Acoustical Society of America
Holm S, Holm T, Martinsen ØG	Simple circuit equivalents for the constant phase element	Plos One
Blachet A, Austeng A, Aparicio J, Hunter AJ, Hansen RE	Multibeam Echosounder With Orthogonal Waveforms: Feasibility and Potential Benefits	IEEE Journal of Oceanic Engineering
Støylen A, Daae AS	Physiological significance of pre- and post-ejection left ventricular tissue velocities and relations to mitral and aortic valve closures	Clinical Physiology and Functional Imaging
Shad EHT, Moeinfard T, Molinas M, Ytterdal T	A Low-power High-gain Inverter Stacking Amplifier with Rail-to-Rail Output	2021 IEEE International Conference on Design & Test of Integrated Micro & Nano-Systems (DTS)
Shad EHT, Molinas M, Ytterdal T	A Two-stage Area-efficient High Input Impedance CMOS Amplifier for Neural Signals	2021 IEEE International Conference on Design & Test of Integrated Micro & Nano-Systems (DTS)
Daae AS, Wigen MS, Fadnes S, Løvstakken L, Støylen A	Intraventricular Vector Flow Imaging with Blood Speckle Tracking in Adults: Feasibility, Normal Physiology and Mechanisms in Healthy Volunteers	Ultrasound in Medicine & Biology
Zadeh SH, Ytterdal T, Aunet S	Subthreshold Power PC and Nand Race-Free Flip-Flops in Frequency Divider Applications	2021 IEEE Nordic Circuits and Systems Conference
Smistad E, Lie T, Johansen KF	Real-time segmentation of blood vessels, nerves and bone in ultrasound-guided regional anesthesia using deep learning	Proceedings - IEEE Ultrasonics Symposium
Bolstad PK, Manh T, Frijlink M, Hoff L	Acoustic Characterization of Inhomogenous Layers using Finite Element Method	Proceedings - IEEE Ultrasonics Symposium
Huynh T, Haugen GH, Eggen T, Hoff L	Nonlinearity in a Medical Ultrsaound Probe Under High Excitation Voltage	IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control
Liu X, Ytterdal T, Shur M	Frequency to digital conversion using Si TeraFETs	Optical Engineering
Mawad W, Løvstakken L, Fadnes S, Grønli T, Segers P, Mertens L, Nyrnes SA	Right Ventricular Flow Dynamics in Dilated Right Ventricles: Energy Loss Estimation Based on Blood Speckle Tracking Echocardiography - A Pilot Study in Children	Ultrasound in Medicine and Biology
Nguyen TT, Espinoza AW, Hyler S, Remme EW, D'hooge J, Hoff L	Myocardial Strain Measured by Epicardial Transducers—Comparison Between Velocity Estimators	Ultrasound in Medicine & Biology
Røed ES, Bring M, Tichy F, Åsjord E-M, Hoff L	Electrical power factor for a single crystal tonpilz versus a plate with matching layers	Proceedings - IEEE Ultrasonics Symposium
Salte IM, Østvik A, Smistad E, Melichova D, Nguyen TM, Karlsen S, Brunvand H, Haugaa KH, Edvardsen T, Lovstakken L, Grenne B	Artificial Intelligence for Automatic Measurement of Left Ventricular Strain in Echocardiography	JACC: Cardiovascular Imaging
Viggen EM, Løvstakken L, Måsøy S-E, Merciu IA	Better Automatic Interpretation of Cement Evaluation Logs through Feature Engineering	SPE Journal
Østvik A, Salte IM, Smistad E, Nguyen TM, Melichova D, Brunvand H, Haugaa K, Edvardsen T, Grenne B, Løvstakken L	Myocardial function imaging in echocardiography using deep learning	IEEE Transactions on Medical Imaging
Smistad E, Salte IM, Dalen H, Løvstakken L	Real-time temporal coherent left ventricle segmentation using convolutional LSTMs	Proceedings - IEEE Ultrasonics Symposium
Smistad E, Steinsland EN, Løvstakken L	Real-time 3D left ventricle segmentation and ejection fraction using deep learning	Proceedings - IEEE Ultrasonics Symposium
Smistad E, Østvik A, Løvstakken L	Annotation Web - An open-source web-based annotation tool for ultrasound images	Proceedings - IEEE Ultrasonics Symposium
Gudala NA, Ytterdal T, Lee JJ, Rizkalla M	Implementation of High Speed and Low Power Carry Select Adder with BEC	Proceedings 2021 Midwest Symposium on Circuits and Systems
Liu X, Ytterdal T, Shur M	Traveling wave TeraFET spectrometer	Proceedings 46th International Conference on Infrared, Millimeter, and Terahertz Waves
Liu X, Ytterdal T, Shur M	Line of sight THz detector using TeraFET spectrometers	Proceedings 46th International Conference on Infrared, Millimeter, and Terahertz Waves
Mekhael G, Morgan N, Patnala M, Ytterdal T, Rizkalla M	GNRFET-based DC-DC Converters for Low Power Data Management in ULSI System, a Feasibility Study	Proceedings 2021 IEEE International Symposium on Circuits and Systems

AUTHOR/AUTHORS	TITLE	JOURNAL
Mirea O, Wulff C, Ytterdal T	Current-reuse Low-Power Single-Ended to Differential LNA for Medical Ultrasound Imaging	International Conference on SMACD and 16th Conference on PRIME
Rahmani M, Patnala M, Ytterdal T, Rizkalla M	Characterization of GNRFET Devices for Applications towards 5G Communication	2021 IEEE International Conference on Design & Test of Integrated Micro & Nano-Systems (DTS)
Grenne B, Dalen H, Nordhaug DO, Sand-Aas T, Holte E, Damås JK, Mjølstad OC	Corynebacterium freneyi as a cause of early prosthetic valve endocarditis	BMJ Case Reports
Hauge SW, Dalen H, Estensen M-E, Persson R, Abebe S, Mekonnen D, Nega B, Solholm A, Farstad M, Bogale N, Graven T, Nielssen N-E, Brekke HK, Vikenes K, Haaverstad R	Short-term outcome after open-heart surgery for severe chronic rheumatic heart disease in a low-income country, with comparison with an historical control group: An observational study	Open heart
Letnes JM, Eriksen-Volnes T, Nes B, Wisløff U, Salvesen Ø, Dalen H	Variability of echocardiographic measures of left ventricular diastolic function. The HUNT study	Echocardiography
Saxhaug LM, Graven T, Olsen Ø, Kleinau JO, Skjetne K, Ellekjær H, Dalen H	Feasibility and clinical impact of point-of-care carotid artery examinations by experts using hand-held ultrasound devices in patients with ischemic stroke or transitory ischemic attack	Journal of Stroke & Cerebrovascular Diseases
Viggen EM, Arnestad HK	Understanding sound radiation from surface vibrations moving at subsonic speeds	Proceedings of the 44th Scandinavian Symposium on Physical Acoustics
Arnestad HK, Viggen EM	A fast semi-analytical method for propagating leaky Lamb wavefields	Proceedings of the 44th Scandinavian Symposium on Physical Acoustics
Estuariwinarno MY, Viggen EM	Determining the inner geometry of a pipe from eccentered pulse-echo measurements in a pipe	Proceedings of the 44th Scandinavian Symposium on Physical Acoustics

Journal articles and Conference Proceedings - CIUS related

AUTHOR/AUTHORS	TITLE	JOURNAL
Walhovd KB, Bråthen ACS, Panizzon MS, Mowinckel AM, Sørensen Ø, de Lange AMG, Krogsrud SK, Håberg A, Franz CE, Kremen WS, Fjell AM	Within-session verbal learning slope is predictive of lifespan delayed recall, hippocampal volume, and memory training benefit, and is heritable	Scientific reports
Fang J, Nasholm SP, Chen W, Holm S	The fractional constitutive models for nonlocal material ased on scattering wave equations	Mechanics of Time-Dependent Materials
Lønmo TIB, Austeng A, Hansen RE	Data-driven Autocalibration for Swath Sonars	IEEE Journal of Oceanic Engineering
Hindenes LB, Håberg AK, Mathiesen EB, Vangberg TR	An incomplete Circle of Willis is not a risk factor for white matter hyperintensities: The Tromsø Study	Journal of the Neurological Sciences
Midtbø H, Hauge SW, Haaverstad R, Dalen H	How reproducible is the diagnosis of borderline rheumatic heart disease?	International Journal of Cardiology
Olsman M, Sereti V, Muhlenpfordt M, Johnsen KB, Andresen TL, Urquart AJ, de Lange Davies C	Focused ultrasound and microbubble treatment increases delivery of transferrin reseptor-targeting liposomes to the brain	Ultrasound in Medicine & Biology
Thavendiranathan P, Negishi T, Somerset E, Negishi K, Penicka M, Lemieu J, Aakhus S, Miyazaki S, Shirazi M, Galderisi M, Marwick TH, SUCCOUR Investigators	Strain-Guided Management of Potentially Cardiotoxic Cancer Therapy	Journal of the American College of Cardiology
Snipstad S, Mørch Y, Sulheim E, Åslund A, Pedersen A, de Lange Davies C, Hansen R, Berg S	Sonopermeation Enhances Uptake and Therapeutic Effect of Free and Encapsulated Cabazitaxel	Ultrasound in Medicine & Biology
Svensson SF, De Arcos J, Darwish OI, Fraser-Green J, Storås TH, Holm S, Vik-Mo EO, Sinkus R, Emblem KE	Robustness of MR Elastography in the Healthy Brain: Repeatability, Reliability, and Effect of Different Reconstruction Methods	Journal of Magnetic Resonance Imaging
Stenberg J, Eikenes L, Moen KG, Vik A, Håberg AK, Skandsen T	Acute Diffusion Tensor and Kurtosis Imaging and Outcome Following Mild Traumatic Brain Injury	Journal of Neurotrauma
Berntsen EM, Haukedal MD, Håberg AK	Normative data for pituitary size and volume in the general population between 50 and 66 years	Pituitary
Clarke GJB, Skandsen T, Zetterberg H, Einarsen CE, Feyling C, Follestad T, Vik A, Blennow K, Håberg AK	One-Year Prospective Study of Plasma Biomarkers From CNS in Patients With Mild Traumatic Brain Injury	Frontiers in Neurology
Thomas N, Støen R, Aker K, Martinez-Biarge M, Nakken I, Håberg AK, Eikenes L	Rise and Fall of Therapeutic Hypothermia in Low-Resource Settings: Lessons from the HELIX Trial: Correspondence	Indian journal of pediatrics
Thon SH, Hansen RE, Austeng A	Detection of Point Scatterers in Medical Ultrasound	IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control
Thygesen SB, Sirevaag TL, Näsholm SP	Novel ultrasonic data processing to detect ultralight cement behind casing - a field study from Utsira High in the North Sea	IEEE International Ultrasonics Symposium
Sulheim E, Hanson I, Snipstad S, Vikedal K, Mørch Y, Boucher Y, de Lange Davies C	Sonopermeation with nanoparticle-stabilized microbubbles reduces solid stress and improves nanomedicine delivery to tumors	Advances Therapeutics
Nawijn C, Segers T, Lajoinie G, Mørch Y, Berg S, Snipstad S, de Lange Davies C, Versluis M	Multi-timescale Microscopy Methods for the Characterization of Fluorescently-labeled Microbubbles for Ultrasound-Triggered Drug Release	JOVE
Snipstad S, Vikedal K, Maardalen M, Kurbatskaya A, Sulheim E, de Lange Davies C	Ultrasound and microbubbles to beat barriers in tumors: improving delivery of nanomedicine	Advanced Drug Delivery Reviews
Olsman M, Mühlenpfordt M, Olsen EB, Torp SH, Kotopoulis S, Rijcken CJF, Hu Q, Thewissen M, Snipstad S, de Lange Davies C	Acoustic Cluster Therapy (ACT®) enhances accumulation of polymeric micelles in the murine brain	Journal of Controlled Release
Snipstad S, Hanstad S, Bjørkøy A, Mørch Y, de Lange Davies C	Sonoporation Using Nanoparticle-Loaded Microbubbles Increases Cellular Uptake of Nanoparticles Compared to Co-Incubation of Nanoparticles and Microbubbles	Pharmaceutics
Arango-Restrepo, Rubi JM, Kjelstrup S, Angelsen BAJ, de Lange Davies C	Enhancing carrier flux for efficient drug delivery in cancer tissues	Biophysical Journal

Presentations - CIUS

AUTHOR/AUTHORS	TITLE	LOCATION
Viggen EM, Løvstakken L, Merciu IA, Måsøy S-E	Better Automatic Interpretation of Cement Evaluation Logs through Feature Engineering	SPE/IADC Virtual International Drilling Conference and Exhibition
Arnestad HK, Viggen EM	A fast semi-analytical method for propagating leaky Lamb wavefields	44th Scandinavian Symposium on Physical Acoustics
Dalen H	Postkardiotomisyndrom	Norsk kardiologisk høstmøte
Estuariwinarno MY, Viggen EM	Determining the inner geometry of a pipe from eccentered pulse-echo measurements	44th Scandinavian Symposium on Physical Acoustics
Grønli T, Wigen MS, Daae AS, Segers P, Støylen A, Løvstakken L, Fadnes S	Model-Based Regularization for Non-Invasive Intraventricular Flow and Pressure Estimates in 4D Ultrasound Imaging	International Ultrasonics Symposium
Pettersen HN, Sæbø S, Pasdeloup DFP, Østvik AR, Smistad E, Stølen SB, Grenne B, Løvstakken L, Dalen H, Holte E	Impact of real-time feedback by deep learning during echocardiography on test-retest variability of left ventricular systolic function measurements	Høstmøte Norsk Cardiologisk Selskap
Viggen EM, Arnestad HK	Understanding sound radiation from surface vibrations moving at subsonic speeds	44th Scandinavian Symposium on Physical Acoustics
Wifstad SV, Løvstakken L, Avdal J, Torp H, Fiorentini S	Automatic quantification of valve insufficiency using 3D Doppler ultrasound and deep learning	CIUS conference
Fadnes S, Sørensen K	Nye metoder for bedømming av blodstrøm	Perinataldagene
Magelssen MI, Hjorth-Hansen A, Andersen GN, Graven T, Kleinau JO, Skjetne K, Dalen H, Mjølstad OC	The clinical influence of hand-held ultrasound examinations by general practitioners in patients with suspected heart failure supported by tools for automatic quantification and telemedicine	Høstmøte Norsk Cardiologisk Selskap
Smistad E, Salte IM, Dalen H, Løvstakken L	Real-time temporal coherent left ventricle segmentation using convolutional LSTMs	IEEE International Ultrasonics Symposium
Smistad E. Steinsland EN. Løvstakken L	Real-time 3D left ventricle segmentation and ejection fraction using deep learning	IEEE International Ultrasonics Symposium
Smistad E. Østvik A, Løvstakken L	Annotation Web - An open-source web-based annotation tool for ultrasound images	IEEE International Ultrasonics Symposium
Smistad E, Østvik A, Pedersen A	Deep learning in real-time ultrasound and digital pathology	Deep Learning Meet Up
Espeland T, Wigen MS, Berg EAR, Salles S, Løvstakken L, Amundsen BH, Aakhus S	Mechanical wave velocities by high frame rate imaging in healthy subjects	Meeting on myocardial function imaging
L. Løvstakken	Machine learning to support the echocardiography examination	DGK – Kardiale Bildgebung
Henry M, Fadnes S, Løvstakken L, Mawad W, Mertens L, Nyrnes SA	Bicuspid aortic valve flow dynamics using blood speckle tracking in children	European Heart Journal-Cardiovascular Imaging

Presentations - CIUS related

AUTHOR/AUTHORS	TITLE	LOCATION
Gudala NA, Lee JJ, Ytterdal T, Rizkalla M	Implementation of High Speed and Low Power Carry Select Adder with BEC	64rd IEEE International Midwest Symposium on Circuits and Systems
Liu X, Ytterdal T, Shur M	Traveling wave TeraFET spectrometer	46th International Conference on Infrared, Millimeter, and Terahertz Waves
Liu X, Ytterdal T, Shur M	Line of sight THz detector using TeraFET spectrometers	46th International Conference on Infrared, Millimeter, and Terahertz Waves
Mekhael G, Morgan N, Patnala M, Ytterdal T, Rizkalla M	GNRFET-based DC-DC Converters for Low Power Data Management in ULSI System, a Feasibility Study	2021 IEEE International Symposium on Circuits and Systems
Rahmani M, Patnala M, Ytterdal T, Rizkalla M	Characterization of GNRFET Devices for Applications towards 5G Communication	3rd IEEE International Conference on Design & Test of Integrated Micro & Nano-Systems

Posters - CIUS

AUTHOR/AUTHORS	TITLE	LOCATION
Bolstad PK, Manh T, Frijlink M, Hoff L	Acoustic Characterization of Inhomogenous Layers using Finite Element Method	IEEE International Ultrasonics Symposium
Midtbø SH, Aanes M, Talberg AS, Måsøy S-E	An efficient finite beam description of stress in a fluid immersed plate using ASM	IEEE International Ultrasonics Symposiom
Pasdeloup DFP, Olaisen SH, Østvik A, Holte E, Grenne B, Sæbo S, Smistad E, Dalen H, Løvstakken L	Real-time Image Guiding in Echocardiography using Deep Learning	IEEE International Ultrasonics Symposium
Wifstad SV, Løvstakken L, Avdal J, Torp H, Fiorentini S	Automatic quantification of valvular insufficiency using 3D Doppler imaging and Deep learning	Probabilistic AI summer school
Wifstad SV, Løvstakken L, Avdal J, Torp H, Fiorentini S	Automatic quantification of valvular insufficiency using 3D Doppler imaging and Deep learning	IEEE International Ultrasonics Symposium
Magelssen MI, Hjorth-Hansen A, Andersen GN, Graven T, Kleinau JO, Skjetne K, Dalen H, Mjølstad OC	The clinical influence of hand-held ultrasound examinations by general practitioners in patients with suspected heart failure supported by tools for automatic quantification and telemedicine	EuroEcho
Hu J, Olaisen SH, Smistad E, Dalen H, Løvstakken L	Fully automated left atrium quantification using deep learning	IEEE International Ultrasonics Symposium

Posters - CIUS related

AUTHOR/AUTHORS	TITLE	LOCATION
Røed ES, Bring M, Tichy F, Åsjord E-M, Hoff L	Electrical power factor for a single crystal tonpilz versus a plate with matching layers	IEEE International Ultrasonics Symposium
Sørensen K, Fadnes, S, Salvesen Ø, Mertens L, Løvstakken L, Nyrnes SA	Assessment of Regional Early Diastolic Intraventricular Pressure Gradients by Blood Speckle Tracking in Children	ASE 2021

Degrees 2021

MASTER THESES

MASTER STUDENTS OBTAINING THEIR DEGREE IN 2021 ON A CIUS TOPIC AND SUPERVISER		
Anette Sollien Nicolaisen	Characterization of Layers with Metal-Coated Polymer Spheres for use in Ultrasound Transducers	L Hoff, PK Bolstad
Hoi Yi Siu	Fabrication and Characterization of a Low Frequency Array for a Hybrid PZT-CMUT Transducer	L Hoff, T Manh, PK Bolstad
Mikael Isak Nilsen	Analysis of an Ultrasound Transducer using a Laser Doppler Vibrometer	L Hoff
Fredrik Feyling	Design Considerations for a Low-Power Control-Bounded A/D Converter	T Ytterdal
Christian Steinsland	Design and Implementation of a Digital Standard Cell Library for 28nm Technology	T Ytterdal
Muhammad Shafiq	Design of Energy Efficient LNAs for Medical Ultrasound Imaging Applications	T Ytterdal
Sanjida Orin Tawhid	ASIC Implementation of a 16-Bit Asynchronous ALU for Ultrasound Application	T Ytterdal
My Tam Lam	Size estimation of Air Emboli in the Brain of Neonates by Ultrasound Doppler	H Torp
Tora Grenness Haga	The Ultrasound Cardiac Supercycle for high temporal and spatial resolution	L Løvstaken
Sigvard Johansen Seljelv	Deep Learning for Deformation Analysis in Echocardiography	L Løvstakken
Amanda Kathrine Jansen	Automatic annotation of structures in echocardiography using deep learning	L Løvstakken
Ivan Krasovec	Investigating systems of white matter integrity and cognitive performance using partial least squares analysis	A Håberg
Emma Bøe Olsen	Acoustic Cluster Therapy (ACT) induced immune response in the brain and characterization of ACT cluster activation	C Davies
Mathilde Riisnæs	Effects of Acoustic Cluster Therapy (ACT) on tumor vasculature in a mouse model of pancreatic ductal adenocarcinoma	C Davies
Gopana Sripalan	Acoustic Cluster Therapy (ACT) and induced immune response	C Davies
Kim Ulvik	The effect of ultrasound on transport of nanoparticles through extracellular matrix	C Davies
Hanne Maren Helgedagsrud	Estimation of nonlinear bulk elasticity parameters for cancer tumor	R Hansen
Sigbjørn Sæbø	Artificial intelligence for improved ultrasound diagnostics	H Dalen
Anders Austlid Tasken	Automated Segmental Cardiac Monitoring by Advanced Computerized Artificial Intelligence on Intra-Operative ThreeDimensional Ultrasound Recordings	G Kiss
Sven Goffin	Improved Strain Computation for Transesophageal Echocardiography Acquisitions	G Kiss, I Balasingham
Anders Emil Vrålstad	Patient Adaptive Beamforming in Echocardiography	S-E Måsøy

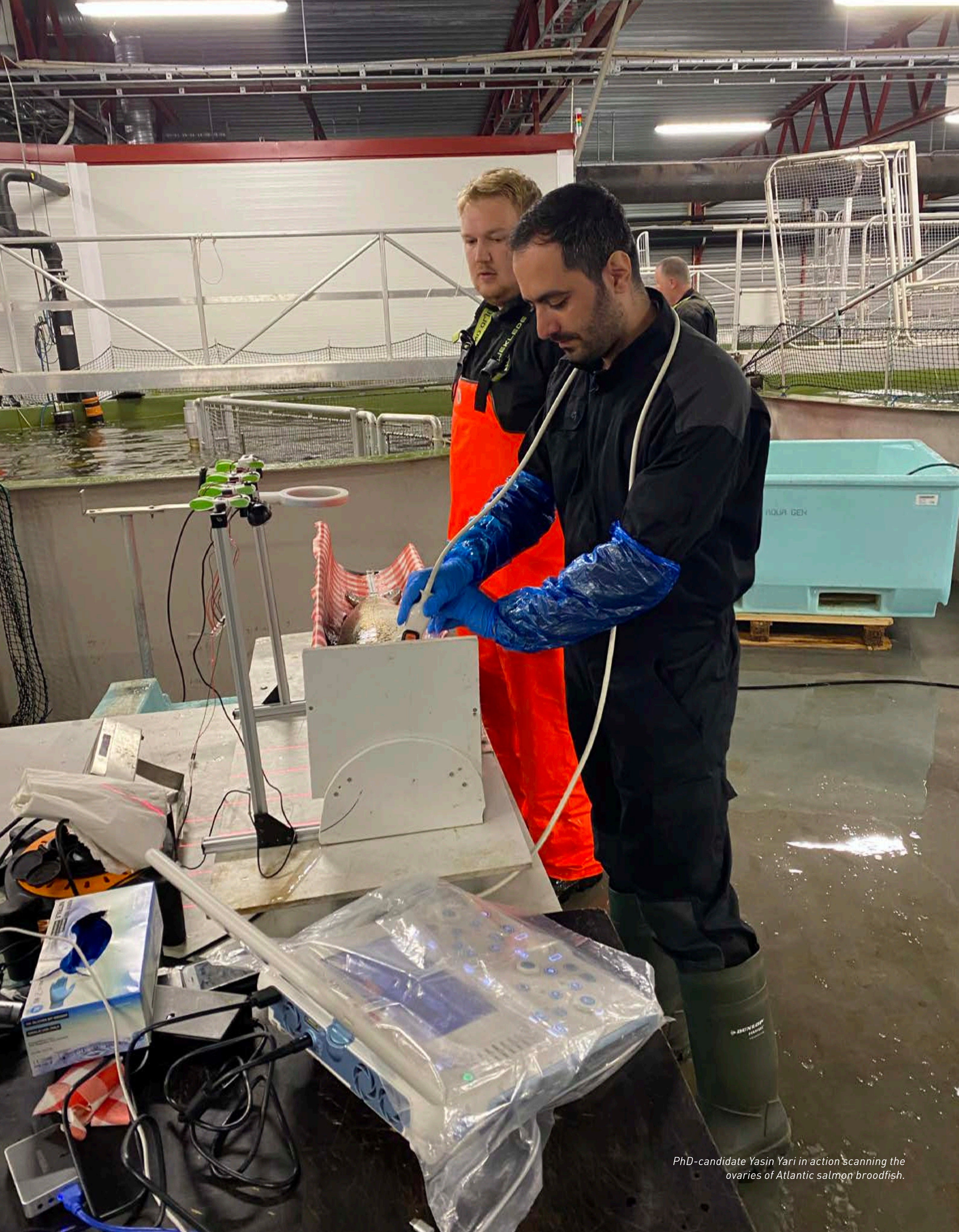
PHD THESES

PHD CANDIDATES 2021 - CIUS FINANCED

Andreas Østvik, NTNU	Automatic analysis in echocardiography using machine learning	L Løvstakken, E Smistad
Antoine Blachet, UiO	Swath sonar: Advanced waveform modulation and associated signal processing techniques	RE Hansen, A Austeng, AJ Hunter, F Tichy, F Prieur

PHD CANDIDATES 2021 - CIUS RELATED

Marieke Olsman, NTNU	Ultrasound and microbubble treatment for improved delivery of nanomedicine to tumours and the brain	C Davies, S Berg
Lars Bakke Hindenes,UiT	Circle of Willis variants and cerebrovascular health: Representations, prevalence's, functions and related consequences Incomplete anatomy and changes to flow appear to induce more unfavorable health outcomes	T Vangberg, A Håberg
Ekaterina Zotcheva, NTNU	Physical activity, cardiorespiratory fitness, and brain health: Evidence from epidemiological studies and a 5-year exercise intervention in older adults	L Erntsen, A Håberg, Ø Salvesen
Jonas Stenberg, NTNU	Outcome after mild traumatic brain injury – The role of neuroimaging findings and preinjury risk factors	A Vik, T Skandsen, A Håberg, KG Moen



PhD-candidate Yasin Yari in action scanning the ovaries of Atlantic salmon broodfish.

www.ntnu.no/blogger/cius/

twitter.com/CIUS_NTNU

www.linkedin.com/company/cius/

www.facebook.com/NTNUhelse/

www.ntnu.edu/cius

Location
NTNU MTFS and ISB, located at Øya, St. Olavs hospital in Trondheim

CIUS NTNU, Faculty of Medicine and Health Sciences,
Department of Medical Imaging and Circulation,
PO Box 8905, 7491 Trondheim, Norway

Contact
Asta Håberg (Centre Director)
+47 902 59 147 / asta.haberg@ntnu.no

Svein-Erik Måsøy (Industry Liaison)
+47 926 25 082 / svein-erik.masoy@ntnu.no

Line Skarsem Reitlo (CIUS Coordinator)
+47 917 21 190 / line.reitlo@ntnu.no

Kari Williamson (Web & Communication)
+47 986 66 928 / kari.williamson@ntnu.no

Thanks to Hege Hovd at NTNU Grafisk senter for
design and production of this report.

cius