

### SFI OFFSHORE MECHATRONICS

# ANNUAL REPORT 2019



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### **ANNUAL REPORT 2019**

### Summary

### HISTORY

SFI Offshore Mechatronics has its origins from the Agder cooperation within the field of Mechatronics, initiated by University of Agder with partners from the local industry related to offshore engineering. This cooperation has been active for several years, and has its origin in the establishment of Master and PhD education to produce needed candidates for the regional and national labour market. Since then, the cooperation has developed to include R&D projects and mobility between industry companies and UiA. During the project period new links between the industry partners and the other universities and research institute partners (NTNU, Aalborg University, RWTH Aachen and NORCE) have been formed.

### ORGANISATION

SFI Offshore Mechatronics is hosted by UiA, Faculty of Engineering and Science. UiA is responsible for three work-packages, NTNU for two, University of Aalborg for one and NORCE for one work package. In addition, NTNU Aalesund and RWTH Aachen participate in different WPs. GCE NODE heads a non-scientific work package for technology vision. The industrial partners are ABB, Bosch Rexroth, Cameron, Klueber Lubrication, Egde consulting, Lundin, MacGregor, MHWirth, National Oilwell Varco, Skeie Technology Consulting and Stepchange. SFI Offshore Mechatronics Steering board consists of 7 partners, where the industry partners hold majority. The Centre Director heads the daily operations, assisted by an administrative manager. The international Advisory Board gives strategic and scientific advice and consists of international experts in the fields of research.

### THE RESEARCH

The main goal is to develop new concepts for autonomous systems where the construction, engineering and design, invite autonomy to minimize the number of manual processes, as well as to reduce risk and cost related to offshore engineering and operations. The research shall result in enabling technologies, equipment, processes and solutions for autonomy and monitoring of heavy machinery, and for handling and analysing large data flows under demanding conditions. The research is carried out in seven work packages: WP1 Drives, WP2 Motion Compensation, WP3 Robotics and Autonomy, WP4 Modelling and Simulation, WP5 Monitoring Techniques, WP6 Data Analytics, IT Integration and Big Data and WP7 Technology Vision.

### Vision and Objectives

### INTERNATIONAL COOPERATION

International cooperation and network is very important in SFI Offshore Mechatronics. There are both international research partners and industry partners in the Centre. The researchers in the Centre have extensive international networks in addition to the actual international universities in the partnership.

#### RECRUITMENT

By the end of 2019 20 PhDs and 2 Post.doc are employed in the Centre. In addition, there are 2 associated UiA funded PhDs included in the centre. Some of these have been recruited from industry partners. This has been a positive experience since the candidates bring valuable industry insight into the research.

### COMMUNICATION AND DISSEMINATION ACTIVITIES

The main platform for presenting results is the SFI Offshore Mechatronics Annual Conference. This took place in Grimstad, June 2019. Over 70 participants got presentations of results and group meetings over two days. SFI Offshore Mechatronics has a web page, a Facebook profile, is on Twitter and LinkedIn. The Centre has an open and including attitude, and several high-school classes have visited, presentations in regional, national and international fora have been given, as well as participation on other relevant arenas.

#### VISION

The SFI Offshore Mechatronics will become the international knowledge and research hub for the next generation of advanced offshore mechatronic systems for autonomous operation and condition monitoring of offshore engineering systems under the control of land-based operation centres, to ensure safe and efficient operation in deeper water and in harsh environments.

The centre shall contribute significantly to growth and innovation in the industry, creating jobs and business with potential both within the target sector, and beyond, such as maritime industry, with a net positive impact on society.

#### MISSION STATEMENT

By 2023, SFI Offshore Mechatronics shall have succeeded in becoming an internationally renowned research-based innovation centre reaching national, international and long-term targets.

National target – develop new concepts for autonomous systems where the construction, engineering and design, invite autonomy to minimize the number of manual processes, as well as to reduce risk and cost related to offshore operations. International target – support the industry partners to strengthen the global position by developing the most efficient and safe future offshore operations.

**Long-term target** – enable technologies, equipment, processes and solutions for autonomy and monitoring of heavy machinery, and for handling and analysing large data flows under demanding conditions.

### GRAND CHALLENGES

The grand challenges are:





## Research Plan/Strategy

### RECRUITMENT

In 2019 22 PhD students and two Post.Docs worked in the centre. They were employed at University of Agder, Aalborg University, NTNU and RWTH Aachen.

### THE RESEARCH PLAN

The research themes of all the positions have been defined in close cooperation with the partner companies. This is to ensure relevance for the industry partners. Several of the candidates are recruited from the industry partners. The 8 year research plan for the SFI (2015-2023) is presented as follows:



#### WORK-PACKAGE 1: DRIVES

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														W	'P1.	5 Sa	ører	n Ke	tels	en	n ( PhD, Aalborg)														
																					WP1.8, New Position (Post.Doc, Aalborg)														

### WORK-PACKAGE 2: MOTION COMPENSATION



### WORK-PACKAGE 3: ROBOTICS AND AUTONOMY

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### WORK-PACKAGE 4: MODELLING AND SIMULATION

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### WORK-PACKAGE 5: MONITORING TECHNIQUES

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### WORK-PACKAGE 6: DATA ANALYTICS, IT INTEGRATION AND BIG DATA



### WORK-PACKAGE 7: TECHNOLOGY VISION

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																						WP7.1 New position (PhD, UiA)													

# The working titles of the positions

- **WP1.2** Using digital hydraulic in secondary control of motor drive.
- **WP1.3** Using digital hydraulic in secondary control of cylinder drive.
- **WP1.4** Electrical and electrohydraulic linear actuators.
- WP1.5 Cylinder direct drive.
- **WP1.6** Energy efficient mobile hydraulic systems with focus on rotary actuation.
- **WP1.7** Energy efficient mobile hydraulic systems with focus on linear actuation.
- **WP1.8** Energy efficient mobile hydraulic systems with focus on digital valve technology.
- WP2.1 Computer vision and 3D sensors for topside automation of offshore drilling.
- **WP2.2** High-performance control for motion compensation.
- **WP2.3** Nonlinear friction compensation in motion compensation systems with significant elasticity.
- **WP2.4** Vision systems for offshore crane control in ship-to-ship operations.

- **WP2.5** Real-time multiple DOF motion compensation using an industrial robot, sensor fusion and conformal geometric algebra.
- WP2.6 Real-time teleoperation and model-based control of cranes with loads.
- **WP2.7** Vision systems for supervision of offshore drilling operations.
- **WP2.8** Fusion of vision, Lidar and IMU data for 3D tracking of objects in offshore crane operations.
- **WP3.1** Development of offshore 3D sensor package.
- WP3.2 Autonomy systems foundation development.
- **WP3.3** Handling of sensor fusion, pointclouds and 3D maps.
- WP3.4 Implementation of situational awareness/human factors concepts for operators using virtual arena.
- **WP3.5** Reliable Communication in 5G.
- **WP3.6** Instrumentation and real-time control of long-reach, light-weight arm intended for use offshore (associated PhD position).

- **WP3.7** Coupled dynamics between vessel and crane (associated PhD position).
- **WP3.8** Formal Methods in Robotics (integrated MSc / PhD position).
- WP3.9 /WP6.5 Sensor fusion for perception, collision avoidance and navigation towards autonomous systems
- **WP4.1** Integrated simulation of multiphysical systems in offshore operations.
- **WP4.2** Component-based simulation systems for drilling automation and crane systems.
- **WP4.3** Protocols and standard for integration of simulation models and co-simulation.
- WP4.4 Modelling and simulation of cable and pulley systems in offshore cranes.
- WP4.5 Modeling and simulation of the motion of ships, cranes and drilling systems in waves
- **WP5.1** Tapered big bearings.
- **WP5.2** Large diameter steel ropes.
- **WP5.3** Fibre ropes.

- **WP5.4** Condition-based lifetime prediction as result of calculated component loads.
- **WP5.5** Modelling the fatigue damage mechanism in welded joints (associated PhD position).
- WP5.6 Monitoring of Hydraulic Cylinders
- **WP6.1** Distributed in-network intelligence across multiple components.
- **WP6.2** Coordinated multi-variable data acquisition, intelligent data reduction, as well as automatic data quality verification and validation.
- WP6.3 Design of soft-sensors based on novel context-aware data fusion techniques
- **WP6.4** Optimization of energy consumption and emission reduction for O&G production platforms.
- WP6.5/WP3.9 Sensor fusion for perception, collision avoidance and navigation towards autonomous systems
- **WP7.1** The management of digital business model innovation

## Organisation

### Work Packages WP1 – WP7

### CENTRE MANAGEMENT

The SFI Offshore Mechatronics centre is hosted by UiA and the management is led by Centre Director, Professor **Geir Hovland** with assistance from Administrative Manager **Anne-Line Aagedal**. In addition, UiA provides necessary resources from the Faculty and Central Management.



Geir Hovland Anne-Line Aagedal Asle Pedersen

**Asle Pedersen** started to work as Innovation Manager in the centre on April 1, 2019. Before joining the centre Asle worked for 13 years at Innoventus Sør in a similar role.



WP-leaders: Olav Egeland, Torben Ole Andersen, Thomas Meyer, Anne Grete Ellingsen, Geir Hovland, Baltasar Beferull-Lozano and Morten Kjeld Ebbesen.

### **WP1**



AAU



WP1 LEADER 2 **Torben Ole Andersen, AAU** Sup. WP1.2, sup. WP1.3, and co-sup WP1.4



### ORGANISATION MAP







WP2.1

NTNU

n

Geir O. Tysse



Supervisor WP2.1-2.4







Dirk Abel RWTH Aachen Sup. WP2.6

WP2.5

WP2.7

Hans Kristian

Holen, NTNU

UiA

UiA Sup. WP2.5





WP2.6 Sondre S. Tørdal Philip Schubert RWTH Aachen

WP2.8

Alexander M.

Sjøberg, NTNU

WP3 LEADER Geir Hovland, UiA Supervisor WP3.1 and WP3.2, Co-supervisor WP3.6, WP3.7

WP2.2

NTNU

Torstein Myhre



NTNU

Sup. WP3.3

WP3.1

UiA

Joacim

WP3.3

Aksel

Sveier

NTNU

Dybedal

Houxiang Zhang NTNU Aalesund

Sup. WP3.4

WP3.2

Aalerud UiA

Thiago G.

Monteiro

Aalesund

NTNU

Atle

Ilya Tyapin UiA Sup. WP3.6



WP2.4

Alexander M.

Sjøberg, NTNU

WP2.3

NTNU

Andrej Cibicik

David Anisi ABB

Co.Sup WP3.2





Charlotte



Ajit Jha UiA

Sup. WP 3.9 Sup. WP 3.5







WP3.5

UiA

Thilina N.



Weerasinghe Subedi



Dipendra Ronny

WP3.7

UIA

WP3.6

UiA



WP3.8

UiA

Landsverk Murray,

Yvonne



Fiyaze UiA

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WP2 LEADER

Olav Egeland, NTNU

Supervisor WP2.1-2.4

Christian Houxiang Holden, NTNU Zhang Sup. WP4.1 & WP4.2 Sup. WP4.3



Geir Hovland UiA Co-Sup. WP4.3





WP4.1

NTNU

WP4.3

WP4.2 Savin Viswanathan Njål Tengesdal NTNU

Lars Ivar Hatledal NTNU Aalesund

WP4.4 Gaute Fotland NTNU

Bjørn Haugen

Co-sup. WP4.4

NTNU

Arne Styve

NTNU

Aalesund

WP4.5

TBA

NTNU

Subtask 5.1 Co-sup. WP4.3



Tor Inge Waag Task leader, NORCE

**WP5** 



Kjell Gunnar WP51 Robbersmyr Martin UiA Hemmer Sup. WP5.1 UiA



Subtask 5.2

«Big steel ropes

WP5 LEADER

NORCE

Thomas J.J. Meyer

Rune Schlanbusch



UiA



······

Subtask 5.3

Big fiber ropes













"Welded

Achim Feldermann Tom Lassen Task leader, Aachen IME

WP5.5

UiA

lan K. Jennions Cranfield U.





WP5.4

Yusuf

Aachen IME

Mohammed



WP5.6 Zbigniew Vignesh Mikulski Shanbhag NORCE

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WP6 LEADER
Baltasar Beferull-Lozano, UiA
Supervisor WP6.1 - WP6.2
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Ajit Jha

Sup. WP6.3

and WP6.5

WP6.5/WP3.9

UiA

Abdur Fiyaze

UiA

Daniel Romero UiA Co. Sup. WP6.1

**Linga Cenkeramaddi** UiA Co. Sup.

**Jing Zhou** UiA Co. Sup. WP6.2



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WP6.1/WP6.4 Luis M. Lopez-Ramos UiA

WP6.2 Emilio Ruiz Moreno UiA

WP6.3 Kevin Roy UiA

APA Ca







### **WP7 TECHNOLOGY VISION**

The purpose of WP7 is to ensure input to the work packages during the 8-year period of the SFI Offshore Mechatronics project. The objective of WP7 is to provide biyearly updates and strategic input on market, technology development and business framework.

WP7 will create an open arena for future trends, barriers and opportunities. In 2019 WP7 held two workshops. The first was on experiences and opportunities with research programs and the second on Machine learnings applications and innovation. In 2019 the SFI board granted WP7 a PhD position on new business models. This will be done in cooperation with the School of Business and Law at UiA.



## Steering Board

The Steering board (2019-2020) consists of 7 members, and 2 deputy members: Leif Haukom (GCE NODE), Charlotte Skourup (ABB), Sjur Henning Hollekim (MHWirth), Morten Halvorsen (NOV), Houxiang Zhang (NTNU), Philipp Schubert (RWTH Aachen) and Geir Grasmo (UiA), Eivind Gimming Stensland (Deputy, MacGregor) and Thor Arne Håverstad (Deputy, Norce).

The majority of the SFI Offshore Mechatronics Steering Board members are from the Industry Partners. The Steering board is appointed for 2 years. It is the General Assembly which appoints the Steering board.





Leif Haukom GCE NODE Chairman

Philipp



Charlotte



Morten Halvorsen NOV



Hollekim

MHWirth



Houxiang Zhang NTNU Aalesund



Thor Arne

Håverstad

Norce

Schubert RWTH Aachen

Geir Grasmo UiA

The Centre has one General Assembly every year, where all partners meet and work-plans for the following year are presented and discussed.

The General Assembly was held on November 14, 2019, where the budget for next three years and the WP annual work plans were presented and approved.

### **KEY NUMBERS 2019**

**Eivind Gimming** 

Stensland

MacGregor

Steering Board Meetings	4
WP leader meetings	10
Workshops	3
Reference Group Meetings	21
Conferences	1
General Assembly	1

### Partners



Partners gathering on the SFI OM annual conference.





# Successful collaboration between the SFI and industry

The close collaboration between regional industry and innovative research at UiA receives praise from the Research Council of Norway. This is reflected in their evaluation of SFI Offshore Mechatronics.

The report concludes with keeping the SFI status and extending funding for the final three years of the scheme.

The research centre at UiA now receives praise from the Research Council of Norway. MHWirth, National Oilwell Varco and Cameron are some of the local industry partners. Despite the downturn in the offshore industry over the past years, all industry partners in the SFI have wanted to continue the collaboration. That impresses both the Research Council of Norway and the SFI management team.

#### **OUTCOMES APPLICABLE IN THE INDUSTRY**

All the research projects in the SFI collaborate with industry partners. Some projects cover topics like hydraulics, motion compensation, robotics, automation and machine condition monitoring.

"There is good co-creation between the researchers and industry partners. The industry reports that the collaboration and the outcomes are useful to them. Formerly, the industry was very development oriented. More are now reporting good progress on research", says Senior Consultant Leif Haukom in GCE NODE and chairman of the SFI.



SFI Offshore Mechatronics get praise and a green light from The Research Council of Norway. They can now keep the project going into the second and last phase of the project period to 2023. In the picture Seunn Smith-Tønnesen, University Director at UiA, Leif Haukom, chairman in the SFI and Geir Hovland, Center Director of the SFI.



The spring of 2019 experts from The Research Council of Norway visited and evaluated the SFI Offshore Mechatronics.

#### PRAISE FROM THE RESEARCH COUNCIL

This spring, the project was midway through the scheme. Experts from NFR visited the centre for a whole day to evaluate the activities of the Centre. The recently published evaluation shows that the centre keeps its SFI-status and funding until 2023.

"We are pleased that we can continue our activities. The evaluation day was an exciting and important day for the SFI. Our centre was selected in 2015, and we got to show the Research Council the work we do and demonstrated that it still fulfils the intentions", Hovland says.

#### THE REPORT FROM NFR IS POSITIVE:

Overall the evaluation team was impressed with the Centre's research. The Centre's research has been reported in a substantial number of peer-reviewed contributions to internationally well recognized conferences and journals. Some work packages have had close research collaboration with obvious synergies. The Centre's wish for further integration across the work packages is endorsed by the evaluation team.

The Research Council is also impressed that the Centre has recruited many research fellows, among them several candidates from the industry.

#### **IMPORTANT TO THE INDUSTRY**

Industry partners were also present during the evaluation this spring.

"A good collaboration with business and industry and regional and international partners is of fundamental importance for the SFI. The centre should contribute to growth and innovation in the sector, create new job opportunities and enterprises with potential for growth both within and outside of the offshore sector", Haukom says.

Haukom has long experience from the industry, both MacGregor and Aker Solutions. MacGregor is an industry partner in the SFI.

Haukom explains that the collaboration with industry partners is strong and that it is important to the SFI, something the Research Council also points out.

"We saw it particularly in 2015 during the downturn in the oil and gas industry. Despite the downturn all the partners wanted to continue the collaboration even though they had fewer resources. This shows how important this project is for the industry", Haukom says.



The Research Council of Norway and the WP leaders visited Mechatronics Innovation Lab at the University of Agder.



### WP5 visits Bosch Rexroth, Netherlands

In December 2018, members of the work package 5 visited the Rexroth cylinder factory in Boxtel in the Netherlands to learn all about condition monitoring features in Rexroth hydraulic and electro-mechanic cylinders.

### WILL STRENGTHEN FURTHER

The SFI wants to look ahead and take on board the feedback from the Research Council. The centre received several recommendations and good advice.

"The response from the Research Council of Norway has been positive. We received feedback that some of our challenges are similar to those of other SFIs. They also said they had learned from us during the evaluation day. That is a positive sign", Hovland says.

One of the recommendations is to communicate research findings more clearly. In addition, the SFI should showcase the great innovation potential for industry. The centre was also encouraged to create more opportunities for PhDs and postdocs to cooperate across work packages.

"These recommendations will further strengthen the centre", Hovland says.

The SFI management has gained useful experiences from the first phase of the project. They also have their own ideas for improvement, which do not emerge from the evaluation.

"For instance, we want to develop so-called spin-off projects and emphasise innovation even more", Hovland says.

### MacGregor's First Contract for Autonomous Mooring



SFI-partner MacGregor has developed a autonomous mooring system for ships without crew. In June 2019 the company got the first contract with Kongsberg Maritime to supply one of the world's first container ships without crew with their mooring system.

«We are very happy about this. It's a breakthrough for us", Jan Martin Grindheim, Director, Floating Solutions at MacGregor says to NRK.

"We have many requests and are seeing an increasing interest", he says.

The mooring system acts as arms on the boat and helps to retrieve the rope and places it on the puller.

The Robotics Group at the University of Agder has played a key role in this project, both as part of the SFI Offshore Mechatronics Centre and an additional spin-off project in the BIA program.

### Scientific Activities and Results



### Algorithm predicting industrial system behaviour

Postdoctoral Research Fellow Luis Miguel López Ramos from UiA and work package 6 is developing an algorithm that can go through a large amount of data and calculate when and where unexpected changes may occur.

#### **ANALYSING DATA**

For the last two years, López Ramos has developed a data analysis method where an algorithm predicts future behaviour in a system based on previous behaviour. López Ramos's algorithm can go through a large amount of data and calculate when an unexpected change may occur. The method can also reveal information about the location of the change point in the system.

"The information we get from predicting the behaviour of a time series of data signals may provide simple and comprehensible explanations for complex phenomena in oil and gas platforms," López Ramos says. >

#### THE METHODS CAN BE TRANSFERRED TO OTHER FIELDS

Data systems in the offshore industry are equipped with sensors which continuously monitor variables such as pressure, temperature and amount of oil flowing through the pipes. Still, it is not easy to know how the system will act at any given time.

"Oil and gas platforms have very complex systems. Technology that can discover behaviour that may lead to system errors will have a large significance for these platforms" López Ramos says.

Even though the SFI mainly helps the offshore industry with innovative mechatronics systems, López Ramos's methods may be of great value for other fields as well.

"His methods are general and not specifically adapted to the oil and gas industry. Therefore, it is possible to transfer them to other fields. In the future, we hope that his algorithms also can be used within health services for treating patients, among other things," Professor and SFI Centre Director Geir Hovland says.



### First PhD defence in the SFI Offshore Mechatronics

**Sondre Sanden Tørdal** successfully defended his PhD thesis on March 19, 2019. The title of the thesis was: "Real-Time Motion Compensation in Ship-to-Ship Load Handling". The title of the trial lecture was "Towards fully autonomous off-shore operation – Challenges and opportunities?" This PhD defence was the first in the research centre SFI Offshore Mechatronics.



PhDs and Post.Docs in SFI Offshore Mechatronics

### Recruitment

The following researchers and technicians were hired in SFI Offshore Mechatronics in 2015-2019.

NAME	POSTITION / INSTITUTION	PERIOD
Torstein Myhre	Post.Doc, NTNU	2015-2017
Geir Olav Tysse	PhD, NTNU	2015-2018
Sondre Sanden Tørdal	PhD, UiA	2015-2018
Achim Felderman	PhD, RWTH Aachen	2015-2017
Atle Aalerud	PhD, UiA	2016-2019
Andrej Cibicik	PhD, NTNU	2016-2019
Joacim Dybedal	PhD, UiA	2016-2019
Shaun Falconer	PhD, UiA	2016-2019
Daniel Hagen	PhD, UiA	2016-2019
Martin Hemmer	PhD, UiA	2016-2019
Sondre Nordås	PhD, UiA	2016-2019
Aleksander Meyer Sjøberg	PhD, NTNU	2016-2019
Aksel Sveier	PhD, NTNU	2016-2019
Thilina Weerashinge	PhD, UiA	2016-2019
Philipp Schubert	PhD, RWTH Aachen	2016-2021
Lothar Wöll	PhD, RWTH Aachen	2016-2019
Zbigniew Mikulski	PhD, UiA (associated)	2016-2019
Viktor H. Donkov	PhD, Aalborg	2017-2019
Thiago G. Monteiro	PhD, NTNU Aalesund	2017-2021

Savin Viswanathan	PhD, NTNU	2017-2020
Njål Tengesdal	PhD, NTNU	2017-2020
Lars Ivar Hatledal	PhD, NTNU Aalesund	2017-2020
Gaute Fotland	PhD, NTNU	2017-2020
Luis Miguel Lopez Ramos	Post.Doc, UiA	2016-2018
Søren Ketelsen	PhD, Aalborg	2018-2021
Emilio Ramiz Moreno	PhD, UiA	2018-2021
Yvonne Murray	PhD, UiA (associated)	2018-2021
Hans Kristian Holen	PhD, NTNU	2019-2022
Dipendra Subedi	PhD, UiA (associated)	2019-2022
Ronny Landsverk	PhD, UiA (associated)	2019-2022
Vignesh Shanbhag	Post.doc NORCE	2019-2021
Mohammed Ysusf	PhD. RWTH Aachen	2019-2023

The centre management and the WP-leaders are actively working on recruitment of female PhD candidates from the master programs at UiA, AAU, NTNU and RWTH Aachen. In general, there are few female master students in the relevant disciplines. The few potential candidates have been actively contacted and motivated to apply for the upcoming positions. The first female PhD candidate in the centre started in 2018, though as an associated PhD financed by UiA. The centre management is also actively looking for female supervisors to join the individual work-packages.

# Communication and Dissemination Activities

SFI Offshore Mechatronics has a web page for news and general information about the project: sfi.mechatronics.no/

The web site is both for partners and the general public. All information about the organization, activities and results that are not sensitive is published here. From the web site there is generated a monthly newsletter, with over 350 subscribers.

The project is also on Twitter (@sfimechatronics), on Facebook (facebook.com/ SFIOffshoreMechatronics) and LinkedIn, (.linkedin.com/groups/2556388) with almost 500 followers.



The SFI Offshore Mechatronics centre wants to contribute in recruiting students to engineering and science. During the year we had visits from the regional high schools to give insight in what we do through tutorial sessions and demonstrations in the Mechatronics lab.



### **Dissemination Activities**

### PUBLICATIONS

#### **JOURNAL PAPERS**

Joacim Dybedal, Atle Aalerud and Geir Hovland, **Embedded Processing and Compression of 3D Sensor Data for Large Scale Industrial Environments, MDPI Sensors, Special Issue on Depth Sensors and 3D Vision**, 2019.

Cibicik, Andrej; Egeland, Olav. (2019) **Dynamic modelling and force analysis of a knuckle boom crane using screw theory. Mechanism and machine theory.** vol. 133.

Damiano Padovani, Søren Ketelsen, Daniel Hagen and Lasse Schmidt, **A Self-Contained Electro-Hydraulic Cylinder with Passive Load-Holding Capability, MDPI Energies** 2019, 12(2), 292.

Atle Aalerud, Joacim Dybedal and Geir Hovland, **Automatic Calibration of an Industrial RGB-D Camera Network using Retroreflective Fiducial Markers, MDPI Sensors Journal, Special Issue on Depth Sensors and 3D Vision,** 2019.

Søren Ketelsen, Damiano Padovani, Torben O. Andersen, Morten Kjeld Ebbesen, Lasse Schmidt: **Classification and Review of Pump Controlled Differential Cylinder Drives**, MDPI Energies 2019, 12(7), 1293.

Lars Ivar Hatledal, Arne Styve, Geir Hovland and Houxiang Zhang: A Language and Platform Independent Co-Simulation Framework Based on the Functional Mock-Up Interface, IEEE Access, August 2019.

A. Sveier, A. M. Sjøberg, O. Egeland, **Applied Runge-Kutta-Munthe-Kaas Integration** for the **Quaternion Kinematics** in Journal of Guidance, Control, and Dynamics.

Thiago G. Monteiro, Houxiang Zhang and Charlotte Skourup, Using EEG for Mental Fatigue Assessment: **A Comprehensive Look into the Current State of the Art, IEEE Transaction on Human-Machine Systems.** 

T. Weerasinghe, I. A. M. Balapuwaduge, and F. Y. Li, **Time-Space Domain Availability Analysis under Reliability Impairments**, IEEE Networking Letters, vol. 1, no., 3, Sept. 2019.

H. V. Kalpanie Mendis, Indika A. M. Balapuwaduge, and Frank Y. Li, **Dependabilitybased Reliability Analysis in URC Networks: Availability in the Space Domain**, IEEE/ACM Transactions on Networking, Early access article, Sept. 2019. (Level-2).

Andrej Cibicik and Eilif Pedersen and Olav Egeland, **Dynamics of luffing motion of a flexible knuckle boom crane actuated by hydraulic cylinders**, Mechanism and Machine Theory, Vol. 143, 2020. Andrej Cibicik, Geir Ole Tysse and Olav Egeland, **Determination of Reaction Forces of a Deck Crane in Wave Motion Using Screw Theory**, Journal of Offshore and Arctic Engineering (Level 2), December 2019, 141(6): 061604.

Sondre Nordås, Michael Møller Beck, Morten Kjeld Ebbesen, Torben Ole Andersen: Dynamic Response of a Digital Displacement Motor Operating with Various Displacement Strategies, MDPI Energies 2019, 12(9), 1737.

Alexander Meyer Sjøberg and Olav Egeland, **An EKF for Lie Groups with Application to Crane Load Dynamics**, MIC, 2019, Vol 40, No 2, pp. 109-124.

Daniel Hagen, Damiano Padovani and Martin Choux, **A Comparison Study of a Novel Electro-Hydraulic Cylinder versus a Conventional Valve-Controlled Actuator – Part 1: Motion Control**, Actuators (MDPI Journal), Volume 8(4), No. 79, 2019.

Daniel Hagen, Damiano Padovani and Martin Choux, **A Comparison Study of a Novel Electro-Hydraulic Cylinder versus a Conventional Valve-Controlled Actuator – Part 2: Energy Efficiency**, Actuators (MDPI Journal), Volume 8(4), No. 78, 2019.

Daniel Hagen, Damiano Padovani and Martin Choux, **Enabling Energy Savings in Offshore Mechatronic Systems by using Self-Contained Cylinders**, Modeling, Identification and Control, Volume 40, No. 2.

Gaute Fotland, Cecilia Haskins and Terje Rølvåg, **Trade study to select best alternative for cable and pulley simulation for cranes on offshore vessels**, Systems Engineering: The Journal of the International Council of Systems Engineering, August 2019.

#### PUBLISHED CONFERENCE PAPERS

Shaun Falconer, Geir Grasmo and Ellen Nordgård-Hansen, **Condition monitoring of HMPE fibre rope using computer vision during CBOS testing**, OIPEEC Conference – The Hague, Netherlands – March 2019.

D. Å. Stave, R. Schlanbusch, D. Vysochinskiy and G. Grasmo, **Condition Monitoring of Steel Wire Ropes**, Submitted to OIPEEC Conference – The Hague, Netherlands – March 2019.

Thilina N. Weerasinghe, Indika A. M. Balapuwaduge, and Frank Y. Li, **Achieving URLLC for Bursty Traffic: Supervised Learning based Arrival Prediction and Dynamic Preamble Allocation**, IEEE Infocom Proceedings (Level 2). Thilina N. Weerasinghe, Indika A. M. Balapuwaduge, and Frank Y. Li, **Preamble Reservation based Access for Grouped mMTC Devices with URLLC Requirements**, IEEE ICC conference.

Njål Tengesdal, Christian Holden and Eilif Pedersen, **Component-based modeling and simulation of nonlinear drill-string dynamics,** Proceedings of the 38th International Conference on Ocean, Offshore & Arctic Engineering

Savin Viswanathan and Christian Holden, **Towards the development of an ocean** engineering library for openmodelica, Proceedings of the OMAE-2019 conference.

Thiago Gabriel Monteiro, Houxiang Zhang, Charlotte Skourup, Eduardo Aoun Tannuri: **Detecting mental fatigue in vessel pilots using deep learning and physiological sensors,** 15th IEEE International Conference on Control and Automation (ICCA), Edinburgh, Scotland, pp. 1511-1516, July 16-19, 2019.

Y. Murray and D. A. Anisi, **Survey of Formal Verification Methods for Smart Contracts on Blockchain**, 2019 10th IFIP International Conference on New Technologies, Mobility and Security (NTMS), Canary Islands, Spain, 2019, pp. 1-6.

Geir Ole Tysse and Olav Egeland, **Control of crane load position using Lyapunovbased pendulum damping and NMPC position control**, 2019 18th European Control Conference (ECC), Naples, Italy.

Daniel Hagen, Damiano Padovani, Martin Choux, **Design and implementation of pressure feedback for load-carrying applications with position control**, Submitted to The Sixteenth Scandinavian International Conference on Fluid Power, May 22-24, 2019, Tampere, Finland.

Nadia Saad Noori and Tor Inge Waag, **Application of Hierarchical Colored Petri Nets for Real-Time Condition Monitoring of Internal Blowout Prevention (IBOP) in Top Drive Assembly System**, 2019 IEEE International Systems Conference (SysCon), 8-11 April 2019.

Viktor Donkov, Torben Andersen, Morten Kjeld Ebbesen, Matti Linjama, Miika Paloniitty, **Investigation of the fault tolerance of digital hydraulic cylinders**, Submitted to The Sixteenth Scandinavian International Conference on Fluid Power, May 22-24, 2019, Tampere, Finland. Ellen Nordgård-Hansen, Håkon Jarle Hassel and Rune Schlanbusch, **Chemometrics as a tool to gain insight into fiber rope aging from infrared images**, Proceedings of the Annual Conference of the PHM Society, 2019.

Lars Ivar Hatledal, Houxiang Zhang, Arne Styve and Geir Hovland, **FMU-proxy: A Framework for Distributed Access to Functional Mock-up Units**, Modelica Conference, 2019.

Philipp Schubert, Sebastian Stemmler and Dirk Abel, **Towards Predictive Anti-Sway Control of Hanging Loads: Model-based Controller Design for a Knuckle Boom Crane**, 18th European Control Conference (IEEE ECC), 25-28 June 2019.

Sondre Nordås, Torben Ole Andersen, Morten Kjeld Ebbesen: **Definition of Performance Requirements and Test Cases for Offshore/Subsea Winch Drive Systems with Digital Hydraulic Motors**, Proceedings of ASME/BATH 2019 Symposium on Fluid Power and Motion Control FPMC2019, October 7-9, 2019, Sarasota, USA.

Søren Ketelsen, Lasse Schmidt, Torben Ole Andersen, Morten Kjeld Ebbesen: **Mass Estimation of Self-Contained Linear Hydraulic Actuators and the Influence on Payload Capacity of a Knuckle Boom Crane**, Proceedings of ASME/BATH 2019 Symposium on Fluid Power and Motion Control FPMC2019, October 7-9, 2019, Sarasota, USA.

Philipp Schubert, Sebastian Stemmler and Dirk Abel, **Development of a Human Machine Interface for Crane-based Load Handling using a Lightweight Robot**, 27th Mediterranean Conference on Control and Automation, 01-04 July 2019.

### **Student Projects**

### UIA

Tomas Lyngroth and Andreas K. Auen, Modelling, Identification and Control of a 5-DOF Shotcrete Robot

Kristoffer Berg and Kai Erik Nilsen, Generic Palletizer with Robot Operating System (ROS)

Asmund Såraa,

A Machine Learning based Prediction Model for Bursty Traffic in 5G mMTC Networks

Andreas Kvalbein Fjetland, Kick Detection **During Offshore Drilling using Artificial Intelligence** 

Kjell André Bakken, Load reduction on wind turbines with the emphasis on shutdown

### NTNU:

Thomas Fredrik Bech Aschehoug Automatic Assembly of Aircraft Parts

Didrik Fjeld Elset, Crane Payload Stabilization using Lagrangian Kinematics and Euler Angles

Eirik Wik Haug Bin-Picking of Industrial Components with Low Texture and Shiny Surface

Trym Dyrkolbotn Hauglund Machine-Vision for Multi-Pass Robotic Welding of Large Subsea Structures

Hans Kristian Holen Vision Systems for Supervision of Offshore Drilling Operations

Dag Lofthus
From CAD Assemblies to Constraint-based Robotic Assembly

Sindre Åberg Mokkelbost Robotic Welding of Large Structures in Aluminum

Kristoffer Nesland Mobile Robot for Inspection of Offshore Production Platform

### AAU:

Frederik Ødum Nielsen

Intelligent Control Design Improving the Energy Efficiency & Dynamic Performance of a Novel Self-contained Cylinder Drive Concept

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