



CEMIS 2021

Annual Report



CEMIS

Centre for Measurement and Information Systems

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Chairmen's review

According to the national RDI roadmap, high quality competences create a foundation that we can utilize in building our ambitious, internationally competitive innovation management that is based on the strengths of our region, business domains and organizations and that supports the regeneration of our society.

Innovation ecosystem contracts between the state and university cities are an essential part of the RDI roadmap's partnership model that aims at strengthening the RDI collaboration between public and private sectors. The purpose of those ecosystem contracts is to facilitate creation of innovation ecosystems aka collaboration networks, strengthen key competence areas and increase the effectiveness of innovation actions in a city-driven way.

Kajaani has unique 50-years long knowhow in measurement technology. The innovation and business environment that started from the measurement technology of forest industry has expanded to cover several other domains such as environmental and wellbeing measurements. Kainuu region's measurement technology ecosystem is strong and versatile covering education, research, development and innovations as well as global business.

Additionally, Kajaani holds a competitive special position as High Performance Computing (HPC) datacenter location where

national supercomputers of CSC are located as well as the incoming LUMI EuroHPC. Due to international, national and regional level significance of datacenter ecosystem, effective data network connections are strategically of primary importance.

Based on these starting points, our innovation ecosystem has two focal points: 1) measurement technology and measurements and 2) high performance computing, artificial intelligence and data centers. These areas have interfaces that can be strengthened through the innovation ecosystem contract. However, they constitute two separate innovation and business sectors that each have their own operational logic and clear, strong and independent role and position in the national innovation politics.

Both strategic focus areas belong to core competencies of CEMIS actors operating in the region and represent the choices of CEMIS collaboration and the common CEMIS strategy. Coordination of Kajaani-Sotkamo innovation ecosystem is managed by CEMIS consortium and supervised by the innovation ecosystem steering board established by the City of Kajaani.



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Rector
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Introduction

CEMIS - Centre for Measurement and Information Systems - is a contract-based centre of teaching and research in measurement technology and information systems that was established in 2010. The CEMIS partners are the University of Oulu, the University of Jyväskylä, the Technical Research Centre of Finland (VTT), CSC – IT Center for Science, and Kajaani University of Applied Sciences.

CEMIS comprises the University of Oulu Measurements Technology Unit in Kajaani (MITY), the School of Information Systems and the mechanical and mining engineering competence area of Kajaani University of Applied Sciences (KAMK), the Kajaani branch of VTT, the Vuokatti Sports Technology Unit of the University of Jyväskylä, and the Kajaani unit of CSC – IT Center for Science (Figure 2.1).

All five of these partners are committed to the work of CEMIS, together with the City of Kajaani and the municipality of Sotkamo. CEMIS is the only innovation centre of the University of Oulu that is not based in Oulu. This university has focused its technology R&D work on CEMIS in Kainuu. KAMK views CEMIS as its principal vehicle for co-operation between universities and research institutes, and as its most important site for development. For the

University of Jyväskylä, CSC and VTT, CEMIS is a form of regional co-operation.

Collaboration between the CEMIS partners includes a joint strategy and management team, co-operation in RDI work, co-ordination of project activities, joint marketing and PR, business development, collaboration in building prototypes, and training in developing shared operating facilities, surroundings and co-operation.

CEMIS values reliability. The CEMIS partners seek to be reliable partners and contributors to their parent organisations, to one another, to their localities, to their customers and to their other partners. CEMIS also ensures the reliability of the measurement technology solutions developed by its partners, and of the measurement results that they provide.

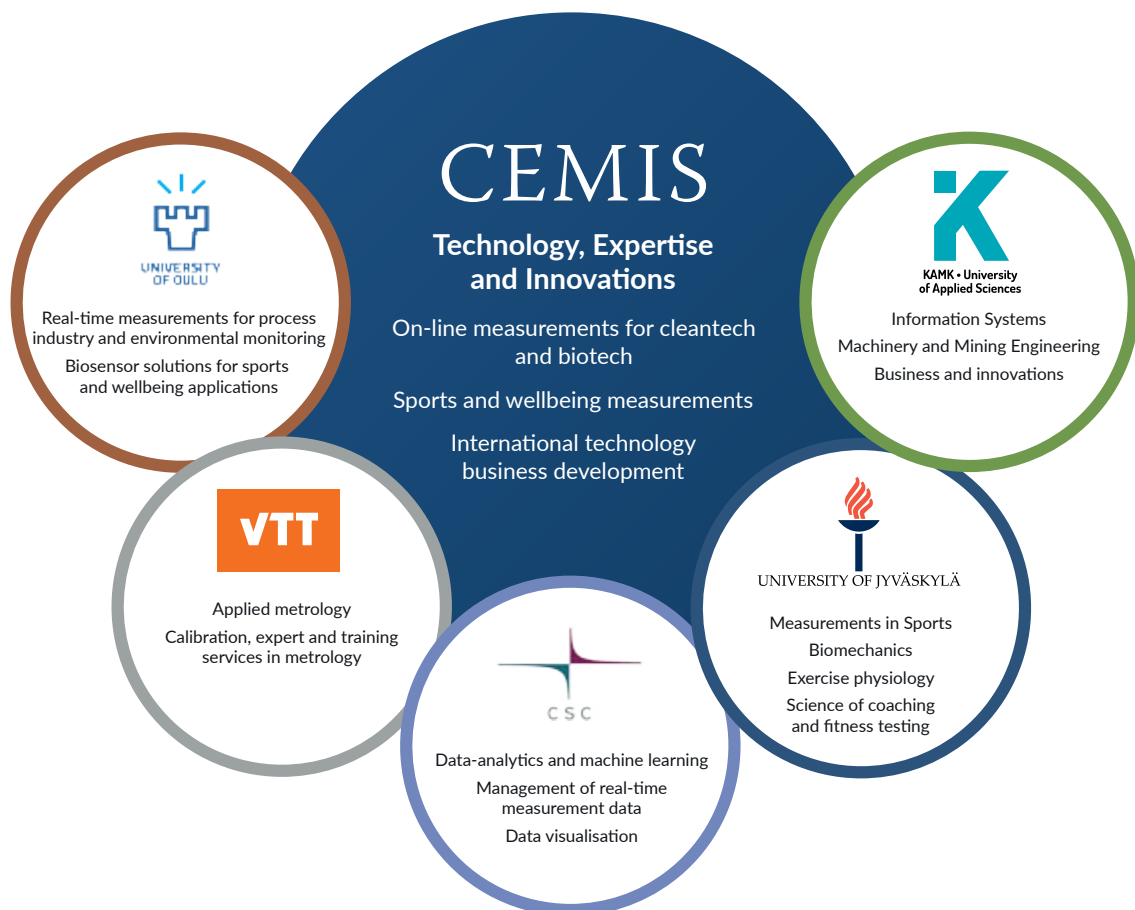


Figure 2.1. CEMIS focus areas and member organisations, with their main areas of expertise.

The technological priorities of CEMIS in teaching, research and innovation are:

- Online measurement solutions to meet the needs of process industries, particularly the bioeconomy, mining and environmental monitoring sectors (Cleantech and Bioeconomy)
- Measurement and testing solutions for sports, wellness and healthcare applications using sensor solutions, and 3D and VR technology-based games and simulator solutions (Sports and Wellbeing)
- Developing international technology business based on the technological expertise of CEMIS and partner enterprises (International Technology Business)

CEMIS provides reliable measuring and information system solutions and services for demanding environments in these fields, comprising cutting-edge R&D services, testing and calibration services, training and consulting, and international technology business development services. This offering applies key CEMIS technologies, including optical spectroscopy, imaging technologies, bioanalytics and biosensors, biomechanical and physiological measurements, power and torque sensors, wireless and embedded IoT sensor networks, data analytics and machine learning, virtual reality and augmented reality (VR/AR), and game technology and computer simulation.

CEMIS seeks to become a sought-after international partner in developing expertise in measurement and information system technology. With its extensive collaborative R&D services and higher education, the expertise and innovation cluster in Kainuu aims to realise internationally significant expertise, new technology and business operations.

By providing R&D services and university-standard education in an innovative and international environment, CEMIS provides new technology, new business operations and cutting-edge expertise for businesses that are developing and applying measurement and information systems. The Centre provides an innovative and international working environment for ambitious researchers and

specialists, and an inspiring learning environment for students seeking to qualify for future specialist positions.

Its mission is to make its teaching and research activities in the field of measurement and information systems increasingly attractive, competitive and effective. To achieve these aims, CEMIS has set quantitative performance targets for its operations in R&D, training and innovation, both for the Centre as a whole and for each individual partner.

The CEMIS development programme is a key tool in the work of CEMIS. It specifies measures to enhance operational co-ordination, collaboration and division of duties, use of shared resources and visibility.

The fifth two-year CEMIS development programme period was continued and ended in the summer 2021 with an annual budget of approximately EUR 1.77 million financed mainly through ESF and ERDF programmes for Northern and Eastern Finland. The total annual funding of CEMIS is more than EUR 12.6 million, consisting of self-financing by the partners, regional development funding (including the CEMIS development programme), and competitively tendered external financing. CEMIS employs nearly 90 specialists in measurement and information systems.

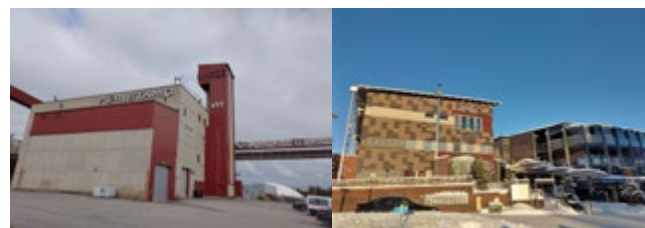
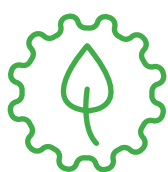


Figure 2.2. Main actors of CEMIS centre are located both in Kajaani and Vuokatti, Sotkamo and RDI operations are performed widely in Kainuu region.

Operational priorities of CEMIS:



CLEANTECH & BIOECONOMY

Measurement solutions for the process and mining industries, and for the bioeconomy



SPORTS & WELLBEING

Measurement and testing solutions for sports, wellness and healthcare applications



INTERNATIONAL TECHNOLOGY BUSINESS

Development of international technology business operations

Director's Review

In 2021, we focused on increasing measurement competences in strategic research areas Sports Technology and Cleantech & Bioeconomy and developed technology competences (AI, data, IoT sensors) that support smart measurements.

CEMIS continued research according to the new strategy and operational plan and the fifth development programme was continued until mid-2021. Thus, we were able to continue RDI collaboration between CEMIS partners and make transition towards the new structural fund program smoother.

Projects of CEMIS development programme have produced excellent results. In 2021, project work has focused on developing measurement techniques for the needs of mining industry, for example, measuring xanthate levels and maintenance condition monitoring, such as vibration measurement and monitoring. Xanthates are toxic chemicals used by mining industry. Even very small amounts of xanthate can have deadly effects on fish species. Therefore, there is a need for very accurate field compatible measurement methods and devices that can measure xanthate levels.

In sports technology domain, CEMIS research activities have included RDI work in improving measurements of trigger pressure in biathlon weapons and developing ski equipment sensors (roller ski sensor, pole force sensor). Sports technology research results can be directly utilized in ski training. Regarding wellness technologies, we have developed rapid measurement technologies, such as cortisol measurements. In the International Technology Business Development research area, we have continued AI-related research, development and innovation work in AI Boost project and increased companies' awareness of utilizing different types of Artificial Intelligence.

In 2021 CEMIS focused on working strongly in national and international research networks. We received access to an international Digital Innovation Hub network DIH-World through an IoT-based measurement pilot. CEMIS and Kajaani University of Applied Sciences started coordinating the national sports technology network LIUKAS and participating in national innovation ecosystem of wellbeing data (HYTKI-verkosto). Despite the COVID-19 pandemic, we were able to deliver fine results, for example, to produce a great number of degrees and publications in 2021. Naturally, the global pandemic had a significant negative impact on some key indicators, such as student exchange.

I would like to thank CEMIS staff for great work and results in 2021.

CEMIS operates and improves its work in accordance with the performance objectives specified in the Centre's operating plan. Outcomes of the centre are assessed in three categories:

education, R&D and innovation activities. CEMIS realised these outcomes with around 85 employees in 2021.

In 2021, CEMIS operations resulted in 32 peer-reviewed scientific articles and 31 conference and professional publications, 8 Diploma/Master's degrees, 21 university of applied sciences Master's degrees and 90 university of applied sciences Bachelor's degrees.

Regarding research & development activities, there were around 20 active projects running in 2021 and dozens of related RDI projects. The fifth two-year CEMIS Development Programme for 2019-2020 was still continued to mid-2021. The content of the programme regarding 2021 is described in more detail later in this report. The funding share of international projects was EUR 0.98 million. Regional funding from the Regional Council of Kainuu or the ELY, Centre for Economic Development, Transport and the Environment was EUR 2.94 million.

In 2021, the RDI operations of CEMIS centre in the field of wellbeing, healthcare and sports focused on improving 3D&VR-based simulation of skiing events and control of ski treadmill as well as integrating virtual models of skiing events to the ski treadmill environment. The development work related to ski tester equipment and ski testing has been connected to the joint project of Finnish Olympic Committee and Finnish Ski Association and research results has been utilized in national team operations. The results from sensor integrations have led to collaboration with Finnish sports equipment manufacturers.

This work has included knowledge transfer, starting collaboration with companies, preparing international research & product development projects together with companies. Companies may have their own RDI projects that are linked to the main project application. Additionally, RDI activities have expanded the selection of wireless measurements and improved repeatability of measurements. Development efforts on base stations has enabled using Coachtech in field conditions. In health technology domain, long term preservative testing for sensor strips has been performed. The results indicate that sensor strips persist more than year.

In the field of Cleantech and bioeconomy, CEMIS centre has actively developed functionality of measurement devices. For example, in MINIME project the focus was on nickel measurements and lactate measurements. Regarding nickel measurements, runoff waters from mines and lake water samples

have been analyzed. In INNOBIO project, process measurements for bio product industry and mining industry have been developed, including online xanthate measurement based on continuous UV-vis spectrum. In order to improve measurement quality, a cleaning system for a measurement head was built.

In TÄRY project, methods of data analytics and machine learning were applied to process and analyze industrial maintenance measurement data. AI BOOST project focused on boosting utilization of artificial intelligence in SMEs by conducting interviews and questionnaires to identify factors driving AI

usage and challenges in utilization of AI. Additionally, the project organized demonstration events where usage of AI technologies was demonstrated to companies in practice. In BIOSAFE project, development of supercritical CO₂ extraction methods continued.

The impact of CEMIS is primarily assessed in terms of new commercially viable technology and by noting how many businesses have been established due to the centre's operations. Two commercially applied inventions were developed and 1 new company was established within CEMIS in 2021.



The Measurement Technology Unit of the University of Oulu (MITY) and technical faculty developed and improved together solubility of lignin fractions, the so-called technical Proof of Concept, transition from technology readiness level TRL1 to TRL3, that enables investing in further refinery of lignin.



Kajaani University of Applied Sciences invested in measurements of environment, water management, data and artificial intelligence, VR/AR technologies as well as continuous learning in their RDI projects. The most significant RDI investment was acquisition of new datacenter environment.



The Vuokatti Sports Technology Unit of the University of Jyväskylä played an active role in implementing National strategy for top-level sports data (HUDS). The purpose of this strategy work is to make Finnish sports research more data-oriented and thus increase the success rate of Finnish top-level sports.



CSC - IT Centre for Science CSC operations at CEMIS in 2021 focused on identification of sports data needs and establishing national collaboration in high performance computing.



VTT Kajaani unit continued strong international metrology development related to work in European Association of Metrology Institutes (EURAMET), International Measurement Confederation (IMEKO) and in several EU-funded research projects. In the latest EU-funded SAFEST project, new methods for improving reliability of measurements related to alternative fuels shall be developed.

Total funding for the Centre in 2021 reached EUR 12.73 million (almost same than previous year) divided as follows: international funding of EUR 0.98 million (2020: EUR 0.96 million), national funding of EUR 1.04 million (2020: EUR 1.31 million), private enterprise funding of EUR 0.97 million (2020: EUR 0.96 million), regional funding of EUR 2.94 million (2020: EUR 3.23 million), and self-financing of EUR 6.80 million (2020: EUR 6.16 million).

The operational environment of CEMIS center looks promising for incoming years. Digital and green transition and objectives set by EU and Finnish Government feed the growth for the research of digital circular economy. The estimated annual growth for global circular economy market is around 8 % but while waste

mountains are growing exponentially there will be very likely demand for new innovative products and services as well as RDI work. The estimated annual growth for sports technology market is around 20 % and this growth is triggered by increased usage of data analytics, IoT sensors and sharing sports data in social media channels.

In the period 2022-2024, the goal is to launch innovation ecosystems (Innovation Ecosystem Contract of Kajaani Region, Arctic Data Intelligence and Supercomputing Ecosystem AIKA) from regional sustainable development funding.

In 2021, CEMIS researchers have participated in dozens of international conferences with their conference presentations (see references in section Publications). Additionally, one new company was established in cooperation between employees of CEMIS partners and students.

Aligned with its strategy, CEMIS will continue to operate as a research and education centre specialising in measurement and information systems, with the main objective of supporting the Kainuu business community and its businesses by bringing new technology, business operations and new specialists to the region. CEMIS continues to focus on three core areas also in the future: Cleantech & Biotech, Sports & Wellbeing, and developing the international technology business. The sixth CEMIS development programme was planned and prepared in 2021 and the key themes of the programme were clarified. The themes of the programme include digital water management competences, wellbeing and proactive healthcare and green transition (circular economy, utilization of side streams).

CEMIS has significantly strengthened the visibility of Kainuu region in national and inter-regional network collaboration during 2021. CEMIS coordinates national sports technology network LIUKAS together with KAMK, participates in national innovation ecosystem of health and wellbeing data (HYTKI) and co-coordinates the innovation ecosystem of Kajaani region together with City of Kajaani. Additionally, CEMIS joined the international Digital Innovation Hub network DIH World in 2021.

Marko Jäntti, Director, CEMIS

Marko Jäntti



CEMIS 2021 in numbers

1

NEW SPINOFF
COMPANIES

2

COMMERCIALY
APPLIED INVENTIONS

10

INTERNATIONAL
PROJECTS

1,06

MILLION EUR IN R&D
SERVICE SALE

32

PEER-REVIEWED
SCIENTIFIC
PUBLICATIONS

8

MASTER'S / DIPLOMA
THESES

TOTAL FUNDING
OF THE CENTRE, EUR

12,73
MILLION

INTERNATIONAL
FUNDING, EUR

0,98
MILLION

NATIONAL FUNDING, EUR

1,04
MILLION

INDUSTRY FUNDING, EUR

0,97
MILLION

REGIONAL FUNDING, EUR

2,94
MILLION

SELF-FINANCING, EUR

6,80
MILLION

CEMIS Development Programme 2019-2021

CEMIS development programmes are a key operational tool for achieving the Centre's objectives and realising co-operation between the CEMIS partners. The fifth development programme (originally 2019-2020) was continued and ended in 2021. The programme was implemented in collaboration between the CEMIS partners, regional businesses and regional development financiers.

The two-year programme was mainly funded through the ERDF programme for Eastern and Northern Finland, with a total budget of approximately EUR 3.57 million. A steering group comprising representatives of CEMIS partners, financiers and businesses guided the programme and its projects. The programme implemented joint technology development projects in technology and application fields that are crucial to the business development of local enterprises, developed co-operation in realising hardware solutions, implemented marketing and PR measures related to the outcomes of the programme, and promoted commercial exploitation of R&D project findings.

The specified general impact goals of the development programme were as follows:

- To reduce industrial CO₂ emissions by developing solutions that enhance bioenergy generating and the mining industry
- To reduce environmental pollution by improving water management in process industries and mining
- To enable cost savings in social and health care by developing solutions for remote health care and independent monitoring of health and wellbeing by members of the public
- To increase national and international RDI funding and corporate funding for CEMIS and the Kainuu region
- To maintain the status of Kajaani as a centre of expertise in measurement technology
- To support the development of Vuokatti into a world-class destination for Nordic skiing
- To give rise to new technology-based spinoff businesses in the operating region
- To improve international business opportunities for technology start-up enterprises in the operating region
- To increase the volume of service research by the CEMIS partners and enhance the commercialisation of research findings
- To increase national and international R&D funding and corporate funding in CEMIS and the Kainuu region

- To match training more effectively to the needs of growth enterprises

Four projects of the CEMIS development programme were running in 2021. BUZTECH project ended in December 2020. Therefore, its results are not included in this annual report.

1. New, innovative and high-quality measurements and processes as part of the biorefinery and mining value chain (INNOBIO)

The INNOBIO project developed measurement solutions for bio, mining and process industries and environmental monitoring in the Kainuu region. This project sought to reduce industrial carbon dioxide emissions by developing measurement solutions for optimising bioenergy generating and mining industry processes.

INNOBIO also worked to develop fermentation expertise (bioethanol production) and to modernise associated existing pilot-scale apparatus. One concrete goal was to adopt artificial intelligence and machine learning environments to appreciate the nature of the data and how it should be processed with a view to realising the desired operation. Another study investigated how measurement uncertainty can be verified when applying artificial intelligence or machine learning. The project was prepared in close partnership with key Kainuu based businesses (including Valmet Automation, St1, Elementis Finland and Terrafame), and accommodates to their needs.

The project measures were divided into five work packages:

1. Strengthening modelling skills for business needs
2. New innovations in the bioproducts industry
3. Process measurements for the bioproducts and extractive resources industry
4. Development of measurement analytics and quality assurance
5. Commercialisation and communication

The total project budget of EUR 940,062 was mainly channelled through the Regional Council of Kainuu (ERDF funding). The project leader is the Measurements Technology Unit (MITY) at the University of Oulu, with the Technical Research Centre of Finland (VTT) as an accompanying participant.

Project results in 2021

WP1. Strengthening modelling skills for business needs

The work in WP1 focused on modeling the water flow with the OpenFOAM application. In 2021, all OpenFOAM research results were gathered.

WP2. New innovations in the bioproducts industry

In WP2, bioreactor runs were performed using a 30-litre bioreactor.

WP3. Process measurements for the bioproducts and extractive resources industry

In 2021, development of continuous online xanthate measurements (based on UV-vis-spectre) was continued. MITY's CE analysis was used to perform comparison measurements for samples taken during maintenance visits. The measurement data is stored on a MITY server. Multivariate calibration is used to calculate the content real-time on the server. Calibration, programming and measurement parameters can be edited and updated remotely. The cleaning system for the measurement head (compressed air) was installed and developed in May 2021 (see Figure 4.1).



Figure 4.1. Installing xanthate measurement devices.

WP4. Development of measurement analytics and quality assurance

In WP4, the project was collaborating with MINIME and TÄRY projects to develop analytics and assure quality. VTT MIKES finalized uncertainty measurements for the device that was developed in the MINIME project. Uncertainty factors related to the device were individualized and boundary values and distributions were defined. In TÄRY project, locations for acceleration sensors in liquid flow calibration devices of VTT Mikes were identified.

WP5. Commercialisation and communication

The work of WP5 in 2021 has resulted in several funding applications (e.g., measurement tools for monitoring water quality, remote controlled biosensor platforms, and electrochemical biosensors for toxicity measurements), and communication and networking activities with stakeholders, such as Water Forum

Finland and Mining Finland.

2. Miniaturised measuring instrumentation solutions for monitoring industrial process and the environment (MINIME)

The project aimed at strengthening expertise in designing, implementing and piloting small measuring devices. It applied expertise in designing and building a small measuring device suitable for measuring lactate when monitoring a fermentation process, and a miniature (portable, drone-mounted) measuring solution for measuring low nickel concentrations. The project yielded new technological solutions for post-project commercialisation through corporate R&D projects. Growth in expertise enabled further application of findings in other fields, such as health technology.

A further goal was to increase the information exchanges between real-time instrument manufacturers, industrial automation system suppliers, the end customers and public authorities. The measurement techniques applied in the project were linked to long-term measurement expertise at MITY and to the use of international networks. Growing expertise, technology transfer and field testing enabled swifter post-project commercialisation of developed technologies for the region's businesses. Another aim was to accompany CEMIS partners to international cleantech trade fairs, where their expertise and technology were marketed and partners were sought for further collaboration and commercialisation.

The total project budget of EUR 278,859 mainly comprised ERDF funding channelled through the Northern Ostrobothnia Centre for Economic Development, Transport, and the Environment (ELY). The Measurements Technology Unit (MITY) at the University of Oulu is responsible for implementing the project.

Project results in 2021

In WP1, *Utilization of patent databases* training event was organized by the Innovation Centre of the University of Oulu on May 5th and 6th, 2021.

The work in WP2 focused on defining the measurement uncertainty of the electrochemical method together with VTT Mikes. In defining the measurement uncertainty, the following uncertainty components were included: Uncertainty components related to preparing the measurement cell, uncertainty components of processing the sample, uncertainty components related to the measurement device and uncertainty components of the calibration curve. In the work package, the preservation study of electrodes was completed. Measurement results showed that electrodes can preserve four months in a fridge and five months in room temperature. Additionally, the operability of the measurement device was verified. The device can also be used for lactate measurements in addition to nickel measurements

(see Figure 4.2).

In WP3, lactate measurements were developed further. In WP4,

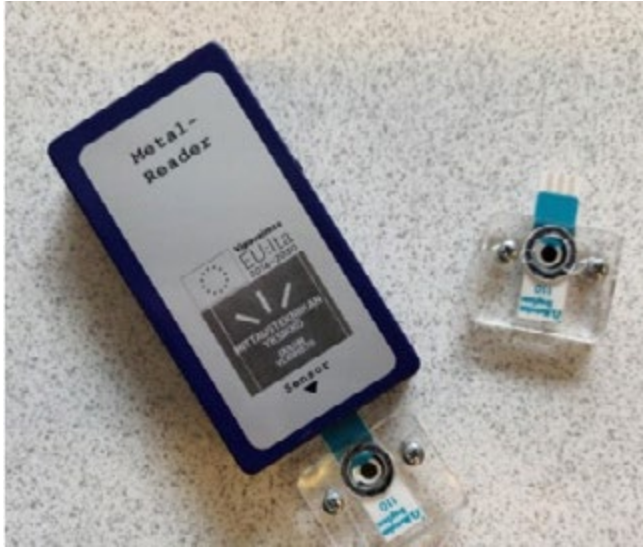


Figure 4.2. MetalReader can also be used for measuring lactate contents.

the samples collected during field measurements were measured in the laboratory with nickel standard increments. Additionally, water samples from the factory of Elementis Finland were analyzed. The samples were measured both with MetalReader and a field measurement cell. In WP5, field measurements were performed with lake water. Water samples were retrieved from a lake (from various depth levels) by using a drone. After that, samples were measured on the beach. The work in WP6 focused on creating a research article on nickel measurements of industry waste waters.

3. Business Co-operation for Industrial Intelligent Solutions (TÄRY)

This project sought to make businesses more competitive by supplementing KUAS expertise and training in operational maintenance solutions for industry and supplying this expertise to businesses during the project. Broader and more diverse operational maintenance training for industry will continue after the project ends, as a part of normal KUAS degree programmes and in-service training. The project developed training for implementation in close partnership with enterprises. Besides improving the availability of enterprise labour and the standard of employee skills in target businesses, the project aimed at improving the energy efficiency of enterprise production processes in line with the goals of sustainable development. The project also strengthened the profile of KUAS as a developer of intelligent solutions for industry and established a form of higher education in Finland that is currently rare but for which the need is evidently growing.

KUAS beared primary responsibility for implementing the project, and partnered with CSC – IT Center for Science, which was responsible for developing operational maintenance measurement data analytics. Project implementation was supported by other

CEMIS partners, with the Measurements Technology Unit (MITY) at the University of Oulu responsible for developing process measurements and the Technical Research Centre of Finland (VTT) working to develop flow modelling. The total project budget of EUR 437,088 was mainly ERDF funding channelled through the Northern Ostrobothnia Centre for Economic Development, Transport, and the Environment (ELY).

Project results in 2021

The WP1 of TÄRY project focused on piloting three courses of industrial maintenance. In WP2, new applications and technologies were introduced to support industrial maintenance training:

1. ACOEM's Falcon and SKF's QC vibration monitoring devices
2. ELMAS industrial maintenance / operational reliability control software,
3. Two demonstration devices of industrial condition monitoring (the smaller designed and implemented during the project and the bigger designed during the project)
4. Solutions for visualizing measurement data of industrial maintenance management (desktop and mobile versions that utilize virtual reality, and one device based on augmented reality)
5. Labview-based exercises of processing vibration measurements (signal processing) for educational purposes.

In the WP2, the work included studying data processing methods

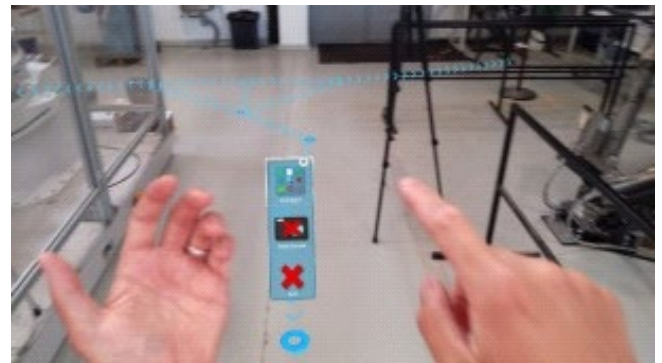


Figure 4.3. Augmented Reality (AR) demonstrator for industrial maintenance.

for industrial maintenance data, introduction of methods and applying modern data analytics for measurement data sets received from companies.

As a part of the results of WP3, two training events were organized: An industrial maintenance training on operational reliability by Ramentor, lubricants and filtering in industrial maintenance by Colly Company. The WP4 involved industry collaboration with ten industry and mining companies and resulted in the start of three theses.

The work in WP5 dealt with dissemination and exploitation of the project results. This work resulted in a newspaper article and the final seminar (webinar) in May 2021. Additionally, in order to exploit project results further, a new RDI project was prepared

together with University of Oulu's MITY Unit and three companies (Metso-Outotec, Terrafame and Valmet). The project shall focus on further development of analysis for industrial maintenance measurements (TEODIMI project, A77557).

4. Innovation platforms for wellbeing, health care and sport (HYTELI)

The goal of the HYTELI project was to develop technologically advanced innovation platforms and environments, and to increase associated global standard technological expertise and competitiveness in Kainuu. The starting point of the project was to apply the interdisciplinary expertise base of the regional CEMIS consortium to themes or sites that are important for regional business, such as preventative health care (health technology, nutritional health, intelligent home care) and the Vuokatti elite sports environment and sports tourism.

The themes were relevant to enhancing measurement technology expertise in Kainuu, increasing the standard and competitiveness of international RDI and developing the wellbeing and tourism industries, and they are also of national and international importance. The development of innovation platforms and environments promoted technological capacity and the stock of expertise, providing a basis for reacting swiftly to the needs of businesses and thereby increasing service business operations and creating new jobs.

Innovation platforms developed in the project were applied both through commercialising innovations (including proof-of-concept), by partnering with businesses and other stakeholders to develop service business operations in innovation environments, and by investing in achieving high-quality and comparable measurement results. The project included significant high-quality new initiatives and global standard special expertise, such as malnutrition among the elderly and an initiative on nutritional supplements: the use of wood industry side streams to promote health and wellbeing - whose economic importance to Kainuu will be considerable in an optimal scenario. The project also sought co-operation in the field of social services and health care, for which an interdisciplinary project consortium may be able to generate solutions for the future. Data analytics, artificial intelligence and machine learning were new methods in application development of intelligent home care and elite sports testing, and it was the right time to adopt them in Kainuu. The project also benefited from the unprecedented interest of the international and Asian winter sports community in Vuokatti, with further rounds of interest to arise.

The project Task Packages were:

TP1: Health technology innovation platforms: a) Nutritional health of an ageing population (e.g., Use of wood side streams to promote wellbeing and health, b) Unlabelled biosensor measurements and other new rapid measurement technologies, c) Quality assurance of health technology innovations, d) Intelligent

home care systems

TP2: Sports technology innovation platforms - from laboratory to field: a) Trials of miniature solutions in sensor technologies for skiing and biathlon, including printable sensors, b) Measurement technology: including determination of the propulsion component in skiing, simulations of elite competition tracks, c) Reaction to needs of the field: Finnish Olympic Committee and sports federation partnership and business co-operation.

TP3: Data analytics, artificial intelligence, and machine learning: a) Increasing the skills of project organisations, b) Pilots: Intelligent home care, dynamic balance, propulsion component in skiing, c) Application of data fusion methods: Visualization and design tool for area or space based on 3D modelling.

TP4: Application of findings: Preparation of national and international projects based on project findings, communication, networking, and publishing activities.

The targeted project outcomes are two commercialised health technology products, two service analytics products and four new service business jobs, and one spinoff enterprise or product in the field of sports technology. The project will also increase the volume of service business for project partners, and seek EUR 1.7 million in national project funding and EUR 1 million in international funding.

The total project budget of EUR 1,452,000 is mainly ERDF funding channelled through the Regional Council of Kainuu. The project is co-ordinated by the University of Jyväskylä (JYU), with all the other CEMIS partners involved in its implementation, i.e., the Measurements Technology Unit (MITY) at the University of Oulu, KAMK University of Applied Sciences, the Technical Research Centre of Finland (VTT) and CSC - IT Center for Science. The project has a strong collaborative link to the KAMK Cemis Business Development team's BUZTECH project.

Project results in 2021

WP1: Health technology innovation platforms

The WP1 of HYTELI has focused on documenting software of Bioreader reader device and performing emulgation studies of aromatic oils as well as antioxidative capacity studies (characterization of pectine sugars). Additionally, cortisol measurements have been investigated as part of rapid measurement technologies. Condition monitoring for cleanroom has been studied and test equipment for pressure difference has been designed and implemented. Terveyskuvastin, "A Health Mirror" concept has been tested in the social & health care learning studio, Studio K, as a part of remote healthcare education. "Terveyskuvastin" demonstrates health monitoring in home environment and provides health care professionals with actual information on a health care customer through several APIs and Gillie.ai platform.

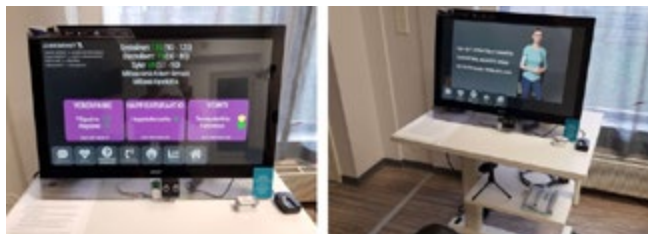


Figure 4.4. Terveyskuvastin, "a Health Mirror" concept.

TP2: Innovation platforms in sports technology

WP2 focused on integrating the Beijing model to the ski mat testbed and adjusting the speed profile of the track. The Beijing model has been tested with biathlon team that has provided positive feedback on the model. The WP2 has resulted in:

- prototype measurement device to measure the trigger pressure with piezoresistive technique. The device has a 9dof inertia sensor and a Bluetooth transmitter & receiver (HW design made by KAMK, SW design by JYU)
- Android-based prototype application for measuring and visualizing the trigger pressure. The application enables drawing the trigger pressure and identified shots to the graph.
- USB and Ethernet versions on base stations (KAMK & JYU)

TP3: Data analytics, artificial intelligence and machine learning

In the WP3 (Data analytics, AI, ML), the Beijing model has been completed (KAMK) and has been tested in skiing lab environment with professional level biathlon athletes (JYU) and individual cross country skiing athletes. Positive feedback has been received from athletes

TP4: Application of findings, communication, networking, business co-operation

The WP4 has resulted in two national level project application (TEM funded LIUKAS Sports Technology Network project, MATINE Maanpuolustuksen tieteellinen neuvottelukunta) and one international project application (Scottish Government Arctic Connections Fund 2021-2022).

Additionally, the work has included dissemination activities such as press release on virtual ski track of Beijing Olympics (virtual modelling expertise and utilization of data fusion methods). The CEMIS Health & Wellbeing newsletter has been in the works. WP4 has also included demonstrations of ski event simulations and how to utilize data fusion methods as well as international (EPSI, ClusSport), national, and regional networking related to the project themes.

The operations of the Oulu University's Unit of Measurement Technology (MITY) and bio-refinery measurement unit

Organizationally, MITY continued to operate with the model of one research group: The active fields still being cleantech and well-being/health. Activities took place in Kajaani and, within the project's scope, Vuokatti.

The main application areas of the research in 2021 were bioeconomy (renewable forest industry, bioenergy, utilization of forest biomass), cleantech (process and environmental applications; especially the extractive industry), and health/well-being applications (biosensor development, nutrition, and development of the Vuokatti area).

The temporary vacancy for a university researcher in imaging measurements continued in 2021 and has been funded jointly by the Oulu Optoelectronics Laboratory project and Kajaani project money. There are authors of postgraduate degrees in both research groups.

The volume of the University of Oulu's operations was approx. 3.75 million euros. Over the year, there were 45 employees, which accumulated approx. 38 person-years. During the year, there were ten people with PhDs in employment and 27% of the person-years.

The biorefinery measurements professorship started in 2019 and stayed at the MITY premises. The professorship is co-financed with the city of Kajaani, Kainuun Liitto, St1 Oy, the University of Oulu, and the Faculty of Technology of the University of Oulu. Professor Mika Ruusunen leads the research. The field of the professorship is related to the automatic optimization of bio-based raw materials, their processes, the measurements of side streams formed in them, and their production efficiency. In Kajaani, the research group, therefore, operates in MITY's premises and the company on the partner's premises.

International projects

The Interreg Nord project „Ice Proof Arctic – Innovations for ice and snow management” continued in 2021. The project validates and develops new ice and snow management solutions for eliminating ice loads on power lines, optimizing the efficiency and safety of renewable electricity production, and monitoring snow loads on roofs.

The measurement technology unit was awarded funding for the Wood for Health project of the ERA-Net ForestValue program. MITY is the leading partner of the project, and the other six partners come from Latvia (2), Norway, Sweden, and Germany (2). The goal of the project is to promote the use of wood in healthcare

buildings by researching and improving the cleanability of wooden surfaces with innovative coatings and by preparing guidelines for the use of wood in the various spaces of these buildings. The project is the first European full-scale research project led by an operator from Kainuu.

The unit's second ERA-Net project SustainIT has continued its work in smart agriculture. Together with partners from Estonia, Sweden, and Germany, we will consider how livestock health and welfare data could be used for the benefit of all operators and consumers in the value chain of the food industry.

The national EIP-AGRI project “Hyvää karjalle” (Good for cattle) cooperates with the Estonian EIP project (EIP, European Innovation Partnership) coordinated by the Estonian dairy cluster. The project develops silage monitoring and agricultural applications for antimicrobial peptides. MITY is the coordinator of the project. Domestic partners are Häme University of Applied Sciences and LUKE Natural Resources Institute of Finland. The innovation group consists of five farms, four companies, two veterinarians, and ProAgria Eastern Finland.

The Northern Periphery and the Arctic - Interreg program granted funding for the bridge project between the program periods called „Looking to the future of technology and innovation in health care”. In the project, MITY, together with the NHS, which organizes health care in the Highlands of Scotland, and the Ulster University located in Northern Ireland, determine the most crucial technology needs for the upcoming program period, assemble the network, and plan a project for which funding will be applied for in the future.

BioSPRINT (EU-H2020): Improve biorefinery operations through process intensification and new end products, process, and measurement development of biorefineries, especially hemicellulose.

OXILATE (Operational EXcellence by Integrating Learned information into Actionable Expertise) is an ITEA project (partners from Belgium, Spain, and Finland). OXILATE focuses on the flexible development and integration of smart analytics and service innovations into complex systems in the industrial customer's operating environment.

In the subject areas of bioeconomy and natural products, international cooperation was carried out in two preparatory projects awarded by different Interreg programs. The ValueStream project was financed by the Baltic Sea Interreg program and the New Natural Kolarctic Products – SME assistance project by the

Kolartik program. In addition, there is cooperation with the Irish Shannon Applied Biotechnology Centre in the Natural Future of Cosmetics project, funded by the local Leader programs.

CEMIS cooperation

CEMIS operations continued during 2021 through the projects in its development program (INNOBIO, MINIME, KAIMIT and HYTELI):

- INNOBIO – New, innovative and high-quality measurements and processes as part of the value chain of the biorefining and mining industry: In the INNOBIO project, the goal is to develop measurement solutions aimed at lower carbon industrial processes and more effective wastewater monitoring, reducing the risk of water pollution. In addition, the goal is to utilize the side streams of the bioeconomy developed by new process technical solutions, the development of fermentation know-how and the modernization of existing equipment.
- MINIME - Miniaturized measuring device solutions for monitoring industrial processes and the environment: In the MINIME project, financed by the Centre for Economic Development, Transport and the Environment of Northern Ostrobothnia, small-sized measuring device solutions are developed for measuring lactate in various industrial applications and for measuring nickel in nearby waterworks of mines.
- HYTELI - Innovation platforms for well-being, healthcare, and exercise: The project is coordinated by the University of Jyväskylä. In the project, the measurement technology unit develops measurements of nutritional markers, completes the biosensor measurement of saliva insulin, isolates and studies compounds with health effects in wood material, sets up various quality tests to be offered as service analytics to companies in Kainuu, and conducts new technology experiments in the field of rolling diagnostics and health & well-being.

Director Vesa Virtanen has participated in the work of CEMIS's strategy group and management team. Professor Mika Ruusunen has participated in the work of the CEMIS management group. The University of Oulu is the largest research participant in the CEMIS development program.

Professor Ruusunen's group's BIOSFE – “Environmentally friendly utilization of bioeconomy side streams - Demonstration of continuous supercritical carbon dioxide extraction” project, which ended at the end of 2021, was combined with the projects of the CEMIS development program into the same steering group at the request of the financier. In the project, continuous supercritical carbon dioxide extraction (SFE) was demonstrated with the equipment manufactured in the project and with the developed automation of the equipment.



Figure 5.1. Continuously operating reactor developed for carbon dioxide extraction (Photo: Petri Österberg, Oulu University).

Other projects

Four projects funded by Business Finland were ongoing in the University of Oulu's CEMIS operations.

- APASSI (Autonomous Processes Facilitated by Artificial Sensing Intelligence) aims to take a step towards the autonomy of industrial processes by developing the reliability and scope of measurement technology with machine learning applications in mind. BF Co-innovation 1.5.2019 -30.4.2021
- HOPE- Highly Optimized Energy Systems The project aims to develop solutions for increasing energy efficiency in energy networks and promote cooperation in the energy sector. The project develops tools and solutions for multi-objective optimization of energy systems. BF Co-innovation 1/08/20 → 31/07/22
- Oxilate (Operational eXcellence by Integrating Learned information into AcTionable Expertise), where digital solutions are developed for, for example, biorefining processes. BF/ITEA3, 1.10.2019 – 30.4.2023
- CEIWA (Circular Economy of water in industrial processes), whose goal is industrial water treatment measurement and control technologies. BF Co-innovation, 1.4.2021 – 31.3.2023

In addition to the CEMIS development program and the Business Finland projects, 22 other projects were underway. There was

business cooperation in the Kainuu area and nationwide with more than ten companies.

The unit is involved in the project „Single-photon detector array for simultaneous label-free Raman and fluorescence lifetime spectroscopy,” funded by the Academy of Finland. This is the development work of the combined Raman/fluorescence lifetime equipment. The project develops a Raman spectroscopy technique that utilizes pulsed light, which can effectively separate Raman and fluorescence from each other.

The Town of Kuhmo and MITY carried out a significant and pioneering study in the Puurakentamisen terveystaikutukset (Health effects of wood construction) project. Its financiers were the regional rural development fund (Kainuu Centre for Economic Development, Transport, and Environment) and the Finnish Forest Foundation. The project monitored the physical, chemical, and microbiological properties of school buildings and student stress and absence during three seasons. The object of investigation was Kuhmo's Tuupala school and Vaala Comprehensive School. The final report of the project was published in December 2021. Regarding communication measures, the project will continue until May 2022.



Figure 5.2. Tuupala school. One of the research locations of the Puurakentamisen terveystaikutukset project.

The goal of the KOS project, implemented with ESR funding from the Centre for Economic Development, Transport, and Environment, is to provide training that meets the needs of the sectors for growth and structural change. As a result of the project, KUC Kajaani University Consortium's learning and competence ecosystem concept was created, which has been put into use permanently. The ecosystem enables modern learning environments for teaching and research and development activities that can be used by companies, universities, vocational training institutions, and research institutes. As a result of the project, the business, expertise, and research networks were integrated, making it possible to utilize research information as part of business development quickly. This is a significant added value for companies. With the help of the ecosystem concept, opportunities are created for companies and KUC to utilize digitalization and artificial intelligence to support production-

economic development. With the help of the pieces of training, the company's product development, competitiveness, and commercialization were accelerated. With the help of the training, skill gaps were eliminated in Kainuu's structural change and growth sectors: 1) bioeconomy, 2) mining industry/cleantech, and 3) health and well-being. In 2021, for example, the following knowledge and skills were transferred to companies:

- Arranged "The Lean and nifty practices in project work" and Praktikum pieces of training. The training highlights the most valuable practices and instills them in one's work on projects and the real-life work environment. With these practices, businesses can keep their projects on schedule and cost-effective.
- Microplastics Research, Disadvantages, and Business Opportunities training
- market and competitor analyses and service design in business operations in the care, health, and wellness sectors
- technology law training for companies, which covered, e.g., Legal issues related to IT business and their effects on business (SaaS, IoT, AI, Big Data) and contracts related to technology and information products
- Management of R&D expertise and transferring know-how models from higher education to global and small and medium-sized enterprises - training, where we were introduced to, e.g., digital twin and predictive analytics
- the critical documents of export trade training were organized for the companies, where, e.g., free trade agreements and legal documents required for export

The Taiga project (1/2020 - 12/2023) studies the health effects of arctic plants. It focuses on the low-grade inflammation and metabolic changes associated with obesity and its associated diseases (diabetes, heart diseases). It is known that a plant-based diet contains compounds that calm this harmful silent inflammatory state and normalize metabolism. The project is looking for valuable substances from northern nature that would have such health benefits. The project studies lingonberry and crowberry to identify their health effects. The project administrator is the University of Tampere's Immunopharmacology research group. MITY participates as a project partner and is responsible for analyzing the berry powders used in the study. The European Regional Development Fund funds the project.

In the PATE project (4/2020 - 3/2022), innovative technological solutions based on the freezing method are developed in cooperation with food, natural product, and wastewater companies operating in Eastern and Northern Finland. The purpose is to study and apply frost concentration in reducing the amount of water in products, thus improving the product's quality. Freeze concentration is based on the natural ability of water to crystallize into pure ice when freezing an aqueous

solution. When the ice is removed, other ingredients - such as flavoring agents and bioactive compounds with health effects - remain unchanged in the concentrated solution. In this way, valuables can be recovered more efficiently. The project utilizes the know-how gained in the previous projects of LUT University and the University of Oulu in developing demo equipment, considering the needs of small companies in particular. The joint project spanning multiple provinces ran by LUT University and the University of Oulu, is financed by the Southern-Savonia County Association and the Regional Council of Kainuu from the European Regional Development Fund.

LuoPro - Natural products, probiotics, and cosmetics activity In the Arctic Biovalley, the EAKR project develops know-how to verify the activity of natural cosmetics and probiotic preparations based on business needs. The measures of the project include, e.g., effectiveness studies of cosmetics (cell tests and skin analyzers), studies of fermented samples (identification and concentration determination of bacteria and investigation of probiotic effects), and complementary analytics development for cosmetics and probiotics. Five companies are involved in the project.

An industrially and commercially developing operating, product development, and piloting environment for bio- and measurement technology (Tbio). The Tbio project (1.12.2020-31.7.2022) supports the planning and implementation of the Arctic Biovalley. The project focuses on increasing the degree of processing of natural materials by micro and SME companies. On the other hand, the project prepares a road map for companies for future validation needs. In addition, industrial piloting and validation of measuring devices are carried out.

Through the Regional Council of Kainuu, Oulu University received funding from the Ministry of Economic Development, Transport, and the Environment for the TELL project (Improving the solubility of lignin produced from industrial side streams and its utilization possibilities in new applications), where the goal was to develop and improve the solubility of lignin fractions produced in Kainuu and to pilot their use as a raw material for the paint and glue industry. The project was implemented by Oulu's measurement technology unit MITY of the Oulu University and KUC Kajaani University Consortium, and the Fiber and Particle Engineering unit.

The most significant result of the project is the „proof-of-concept” process, which allows the solubility of lignin to be significantly improved, enabling its beneficial use in, for example, the adhesive industry and thus developing new bio-based products based on it. With close cooperation with Kainuu companies and business life and using lignin produced in St1 bioethanol production as a starting material, the project developed a processing method in which the TRL (Technology Readiness Level) level was raised from idea (TRL 1) to concept (TRL 3). A research project supporting business and business life was planned to utilize the project results.

In the TEODIMI, industrial process management with digital tools and measurements project, the prerequisites for industrial operations in line with sustainable development are developed by utilizing new tools and operating models made possible by digitalization. This is implemented by comprehensively developing industrial process measurements, process equipment condition monitoring measurements, and the comprehensive utilization of these measurement results and environmental impact measurements of processes. The project is implemented by MITY and KAMK.

MITY has a proof-of-concept section (PoC) in the large-scale project „Luonnossa menestyvät istukkaat” (Survival of stocked fish in the wild), coordinated by the Finnish Natural Resources Fund and partially funded by the European Maritime and Fisheries Fund. The project aims to develop a field-ready measurement of the stress hormone cortisol, suitable for the pool water of a fish farm.

The increased use of plastic products, inadequate material recycling/collection systems, and traffic contribute to a global threat - harmful plastic is found in waterways, soil, and even the atmosphere. Tiny plastic particles quickly become microorganisms and eventually move into the entire food chain. International research related to the problem has started, including, e.g., evaluation of the health effects of plastics, development of substitute and more nature-friendly materials, ideation of collection techniques, and application of measurement technology to the observation and identification of plastics.

University of Oulu's Kajaani Measurement Technology Unit MITY and Kajaani University of Applied Sciences KAMK have launched

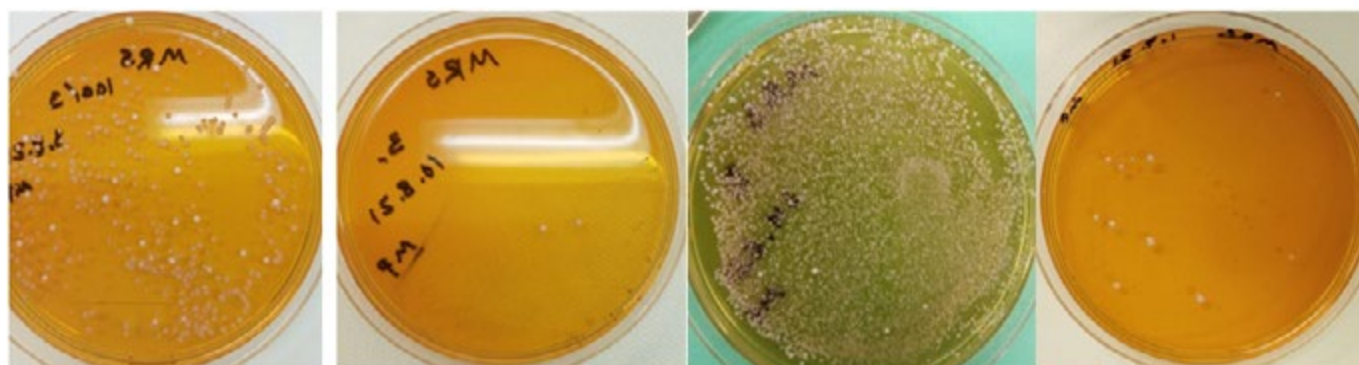


Figure 5.3. Inspecting the bacterial growth of the LuoPro project's Kombucha products on a lactic acid bacteria plate.

an ERDF project regarding this theme. The REMMI project aims to develop a compact field device for real-time observation of microplastics in waters. The project is at a stage where the microplastics measurement method has been comprehensively tested. We have built a functional measurement on the optical table based on the results. After additional tests, it's time to design and implement the field device. KAMK has found the most common microplastic sources and transport routes in the water systems of the Kainuu area and tested new filter materials for removing microplastics. Commercialization paths are being devised for the measurement system to be developed. The project is for two years, ending at the end of 2022.

A digital leap in oral health - towards a virtual reception in the project, the dentist's virtual reception is demonstrated and tested. This is ERDF funding from the Northern Ostrobothnia Association.

MITY also carried out a preliminary survey that mapped the technology needs of care homes. It was an ERDF project financed by the corporate finance side of the Kainuu Center of Economic Development, Transport, and the Environment.

Research collaboration and publications

Preparations have been made to start cooperation with the University of Eastern Finland's School of Pharmacy and Applied Physics departments regarding wood biomasses. With Kai Peiponen, professor emeritus of the Joensuu campus, and his group, we continued the measurement method research regarding a global and severe problem - microplastics in waterways. The research is ongoing.



Figure 5.4. A pole force sensor in the HYTELI project

International cooperation was actively carried out with more than ten research institutes, e.g., Sweden, Norway, Latvia, Italy, Germany, Denmark, Estonia, Northern Ireland, and Great

Britain. The number of scientific articles was good; 18 refereed international scientific papers and professional and conference publications/presentations. The unit members participated in international and national evaluation tasks (scientific journals, evaluation of international project applications).

Operations of Kajaani University of Applied Sciences

Year 2021 brought relief to difficult times caused by COVID-19 pandemic. Teaching tasks were performed during the spring in a hybrid mode but in the autumn 2021 many staff members returned back to the campus, however, remote work contracts were still continued. Student groups were full in almost all education areas and we also received a number international students but not in normal levels. The technology competence area of KAMK produced 134 degrees and 63 publications.

RDI operations were performed according to the project plans in 2021, of course, project related traveling was almost non-existent. Funding for new RDI projects was applied and projects were planned although the opening of the new EU funding period was open. The RDI volume of KAMK was 3 963 022 €, where technology competence area's portion was 1 774 305 € (45 %).

The largest volumes regarding service business of the technology competence area was condition measurement, EMC testing and VR/AR services. Additionally, software business volume increased, for example, Fingrid bought services from KAMK as a new customer.

We continued further environmental measurements, water management measurements, sports measurements, data & AI & VR/AR technologies and developing continuous learning in our projects.

Our most significant RDI investment was acquiring a new data center environment with the cooling system. The value of the acquisition was almost 300 000 €.

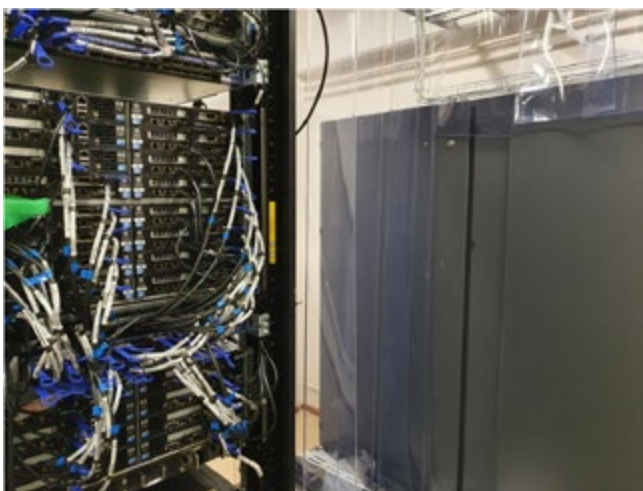


Figure 6.1. New data center environment of KAMK.

In the laboratory of Greener project we study impacts of climate change on plants and substrates. The laboratory was acquired in 2021 (see Figure below). The project manager of Greener project is Mr. Antti Rimpiläinen.



Figure 6.2. Greener project laboratory at KAMK.

WaterPro project that was performed together with University of Oulu, Kerttu Saalasti Institute and other partners continued in demanding winter conditions with field tests in Pyhäsalmi mine with the pilot environment designed and implemented by KAMK. The project manager in the project from KAMK's side was Esther Takaluoma, project engineer Jani Heikkinen and the project manager of the whole project consortium was professor Ulla Lassi from the University of Oulu. See pictures from active project work below.



Figure 6.3. Piloting in winter conditions.



Figure 6.4. Designing and implementing pilot environment for water management purposes.



Figure 6.5. Research environments of CEMIS are very diverse.

The project staff consisted mainly same employees than in 2020, however, some new employees were recruited. A Tenure Track position that is well known in academy was opened in Autumn for technology competence area and PhD Petri Koponen was selected to the position. This position was used to strengthen the RDI profile of KAMK.

Collaboration with Raahe continued further in 2021. This time we started day groups of construction & civil engineering engineers and ICT Bachelors of Business Administration and the blended learning student group of machine engineering. Additionally, we continued planning of From Data to AI engineering education that shall be partly implemented in the facilities of CSC in Espoo, Keilaniemi starting from Autumn 2022.

CEMIS Business Development Unit 2021 – AI shall boost the business

Starting 2021, the AI Boost project was launched at the CEMIS Business Development unit of Kajaani University of Applied Sciences. The project is part of the department's dedicated efforts to build a thorough understanding of and leverage Artificial Intelligence use in SMEs at local and national scales. Spearheaded

by Dr. Anas Al Natsheh, a devoted technology commercialization expert and project manager at KAMK, the AI Boost (ELY 2021-2022) is a powerhouse project to support national initiatives towards boosting innovation in businesses by promoting AI expertise and the utilisation of artificial intelligence in companies.

Through carrying out a nation-wide benchmark survey, the AI Boost project aims to identify and describe the existing status quo of artificial intelligence use in Finnish SMEs, including drivers and barriers to adoption factors, as well as potential effects on organizational performance and strategies. To this aim, 24 B2B interviews were conducted in 2021, out of which a conference paper was developed and presented in the ICERI 2021 conference event, entitled „What is an Artificial Intelligence (AI): A simple buzzword or a worthwhile inevitability?“ (S.A. Gbadegeshin, A. Al Natsheh, K. Ghafel, J. Tikkanen, A. Gray, A. Rimpiläinen, A. Kuoppala, J. Kalermo-Poronen, & N. Hirvonen). A shorter artificial intelligence brochure has also been issued for companies and other potentially interested stakeholders, and an industrial report was developed and intended for publishing in the current year 2022.

In addition, the project aims to pilot-run successful Artificial Intelligence Technology demonstrations to local and regional SMEs to provide an understanding into ways they could turn existing AI-based innovations to marketable product and/or service portfolios and streamline their operational and strategic processes. The latter tech-demo measures were planned in the initial phase of the project, and implementation started in the beginning of 2022. In addition, various support measures were implemented to support the CEMIS business technology, such as surveys on the outlook of the gaming industry, circular economy trends, and the market potential of various early-stage innovations.

Another significant project that the CEMIS Business Development (CBD) unit will be implementing in 2021-2022 is ELY's ESR-funded project: AI - Artificial Intelligence for Improving the Quality of Education and Student Success, AI-EDU. The project introduces and tests the functionalities of student communication assisted by information systems. It also supports the preparation, implementation and testing of artificial intelligence-based methods that develop KAMK's teaching activities and student interaction. The aim is to provide training in artificial intelligence-supported student interaction functionalities and teaching activities to ultimately improve learners' academic performance, increase knowledge and skills, and accelerate their individual learning paths. The new methods are sought to increase the quality of teaching activities and the speed of decision-making in teaching, as well as resource efficiency. These include artificial intelligence-supported courses, developed to support more independent study and increase learning in the most critical subjects on KAMK's online study platform "Edukamu". Another significant innovation is KAMK's chatbot, the design and implementation of which have carried

out in this project. Kit-chatbot was applied on KAMK's intranet platform at the end of the year and deployed on the website for more extensive at the start of 2022.

Towards the end of the year, CBD launched the DigiLead project (ELY, ESR), to help provide company leaders with the knowledge and tools needed for a successful development and implementation of a digital strategy. The training aims to develop better management skills related to digitization and introduce participants to various digital tools supporting the pathway to digitalization. The tools introduced are aligned with organizational goals and the strategic orientation of SMEs to ensure optimal benefits and long-term growth. The project also aims to collate open-source technologies for companies without the budget for costly paid options, as well as develop clear guides and materials training local and regional businesses on how to utilize them. The core behind DigiLead project is rooted in regional needs for understanding digital solutions at company levels, and the challenges associated with the early-stage implementation of digital strategies, identified through former CBD projects.

In summary, activities at the CBD department involved a thorough primary and secondary research work as well as the development of various industrial reports and academic publications. The pandemic affected the dissemination of project results, with the restrictions of on-site events, but plenty of new information was available, for instance, through webinars.

Operations of VTT Technical Research Center of Finland in Kajaani

In Kajaani, VTT focuses on metrology activities to improve and ensure the reliability of measurements in industry. The Kajaani laboratory of VTT MIKES is the world's northernmost National Standards Laboratory. It offers high-level measurement and calibration services to domestic and foreign customers. The laboratory has been operating since 2011 in purpose-built premises at Renforsin Ranta Business Park.

As the National Metrology Institute (NMI) of Finland, VTT MIKES is responsible for implementing the SI measurement unit system in Finland. As part of a global network of metrology institutions, VTT MIKES takes care of the development, maintenance, and international equivalence of national measurement standards, i.e., national reference equipment. VTT MIKES develops new methods and technologies for companies to implement reliable measurements and metrological traceability of measurements. Comprehensive calibration services make it possible to verify the quality of measurements in the industry in an internationally credible manner.

The Kajaani site houses the national measurement standards for force, torque, fluid flow, and mass in an area over 20 kg. The activities here are focused on calibration and related research activities. Measurement standards are used to calibrate measuring devices, i.e., to determine how much the reading

displayed by the device being calibrated differs from the true value. The most accurate measurements in Finland are made with VTT MIKES equipment. National and international cooperation with other actors and stakeholders in the field is an integral part of the laboratory's operations.

In 2021, both traceability services and research activities developed according to expectations. The number of personnel remained unchanged (7 people). The number of customers has also remained the same year after year, being approximately –250 customers per year. More than 95% of the customers are from outside the Kainuu region. There are more foreign customers than customers in Kainuu. During the years of operation, it has been observed that the location of the laboratory is well suited and appropriate to the purpose from the point of view of the customers.

An international operator

The Kajaani laboratory actively participates in international cooperation. International comparison measurements and contributing to the work of technical committees in the European Association of National Metrology Institutes (EURAMET) are essential parts of the unit's technical activities. Finland's representatives in EURAMET's fluid flow technical committee (TC-F) and IMEKO's (International Measurement Confederation) TC3 (Measurement of Force, Mass, and Torque) technical committee are from Kajaani. In 2021, the international EURAMET comparison of liquid flow was carried out in the measurement range of 30 m³/h to 200 m³/h. Metrology research was carried out in four projects of the European Metrology Research Program (EMPIR) (MetroWaMet, ComTraForce, WinDEFKY, and SAFEST). In these projects, new methods are developed that can improve, for example, the reliability of household water measurements, mechanical testing of materials, torque measurements important for wind energy production, and transport fuel measurements. The MetroWaMet project, which ended in 2021, developed test equipment that can be used to study the dynamic properties of water flow meters in the flow range 0.05 m³/h -3.3 m³/h.



Figure 7.1. Petri Koponen and Martti Heinonen in the Kajaani laboratory of VTT MIKES.

Future from research

VTT MIKES develops its expertise and services in joint and self-financed research projects to meet the future needs of customers and other stakeholders. In addition to the international research projects mentioned above, our Kajaani laboratory participated in 2021 in three CEMIS development program joint projects INNOBIO (New, innovative, and high-quality measurements and processes as part of the value chain of the biorefining and mining industry), HYTELI (Innovation platforms for well-being, health care and exercise) and SMASH-GTA (Smart Sensors and Hardware for Green Transition Approach).

HYTELI is a project coordinated by the University of Jyväskylä, where VTT has developed measurements and measurement methods for ski equipment. The project developed a roller ski prototype that can be used to measure the vertical and lateral forces applied to the ski during skiing. The prototype was tested in 2021 using VTT MIKES' force reference equipment, which provided important information about the reliability of the experimental and computational results.

In the INNOBIO project, VTT MIKES developed computational flow dynamics capabilities in Kajaani to make complex models with moving parts work in a computing environment. Also, measurement uncertainty calculations were carried out for MITY's measurement methods.

In the SMASH-GTA project, VTT MIKES and KAMK's CEMIS explore the use, benefits, and limitations of IoT technologies, especially in monitoring waste containers.

VTT MIKES also participated in the Smart Water Management project funded by Business Finland, utilizing its expertise in evaluating measurement reliability and water flow measurements.

Visions of the future, 2022-23

The outlook for operations in 2022 is good. The operations of the Kajaani unit will be integrated into the operations of the Process Metrology team, which opens up new opportunities to expand the unit's operational area and customer base.

Together with other CEMIS operators, two new CEMIS development program projects are being prepared. In 2022, VTT will self-finance the development of expertise in ultrasound technology in Kajaani, which will continue to be developed in jointly funded projects. The field of application is liquid flow measurements - especially for the needs of the circular economy.

Among companies, the meaning and importance of the reliability of measurements have continued to grow because reliable measurements bring quality, market value, and competitive advantage. The share of traceability services in the budget of VTT MIKES Kajaani is expected to be strong in 2022 as well. Participating in international research and comparison measurement projects maintains a high metrological level.

The operations of University of Jyväskylä in Vuokatti

General operations

The Vuokatti sports technology unit of the University of Jyväskylä has coordinated the Sports and well-being expertise area of CEMIS since 2010. Over the course of ten years, the unit's operations have strongly focused on the development of measurement technology and applied research to serve, especially the testing and training of athletes in Nordic sports - keeping in mind the applicability and broader usability of the results and methods. The multidisciplinary CEMIS cooperation has supported this purpose excellently.

The unit continued to act as an active partner in the national implementation of the data strategy work for elite sports (HUDS), which includes the Finnish Olympic Committee, the Finnish Institute of High Performance Sport KIHU, and CSC - IT Center for Science. The strategy work aims to make the development of Finnish sports research more data-oriented and, through this, to increase Finnish top-level sports success. Data issues were also strongly present through the unit's other project activities. Among other things, the planning of the new CEMIS program, in which data should play a significant role, also started in 2021, and this should also guide the goals and contents of CEMIS joint projects. In addition, as part of the Data-based movement - ERDF project, exercise data issues were at the center of the project; the aim has been to start activities for the development of exercise data expertise in cooperation with the municipalities of Kainuu, but also to advance the exercise instructor training at Kajaani University of Applied Sciences to increase students' data understanding.

The total number of the unit's personnel in 2021 was 17, nine working full-time. The head of the unit was professor Vesa Linnamo. Those who worked part-time for the university either worked for the Finnish Ski Federation, the Finnish Olympic Committee, KIHU, or the Olympic Training Center Vuokatti-Ruka in addition to the university or focused on sports, taking the new know-how and methods developed in projects and research to active use on the field.

The unit's staff published 14 scientific peer-reviewed publications during the year. A record eight dissertation projects were underway. Four master's degrees in exercise technology were completed in the unit during the year. There were 12 ongoing projects; HYTELI/CEMIS (ERDF), From an athlete test to an international product in Vuokatti (ERDF), Dual career in exercise technology (ESR), Development of expert functions at the Olympic Training Center Vuokatti-Ruka (ERDF), National special task for competence development (OKM), Dissertation researcher's grant (Ameri Cultural Foundation), Data-based movement (ERDF),

NaisQs research (OKM), Textile sensor development project (Riga Technical University), Älylatu - New service innovations in skiing (ERDF), LIUKAS network project (TEM, ERDF) and High-altitude research project (ERDF), which will be discussed in more detail below.

A project example

In the high-altitude research project, the unit carried out the high-altitude measurement phase during the spring-summer of 2021 with the Helsinki Sports Medical Center (HULA) and the Finnish Institute of High-Performance Sport KIHU. The experimental group consisted of 16 top athletes, and the control group consisted of eight top athletes from the Vuokatti-Ruka Sports Academy. The experimental group lived in the Vuokatti Sport's high-altitude apartments for one month. During this time, the athletes followed their spring training program and did two controlled hypoxia exercises per week (Figure 8.1.). Similar research in Finland, where people live at high altitudes and train at low altitudes, has never been conducted on such a large scale.

Before and after the hypoxia period, the athletes underwent treadmill tests and blood tests. Hemoglobin mass determination was the most important blood variable whose effects of changes on performance were to be investigated. The experiment was continued for some athletes for another month with the so-called IHE (Intermittent Hypoxia Exercise), where the athlete was exposed to two hours of hypoxia either in an alpine hut or with a hypoxia generator and a one-hour run at the corresponding altitude with a hypoxia generator. The results showed that some athletes benefited from high-altitude training in this form. Some IHE group members could increase or maintain HB mass even with IHE exposures after the high-altitude period.

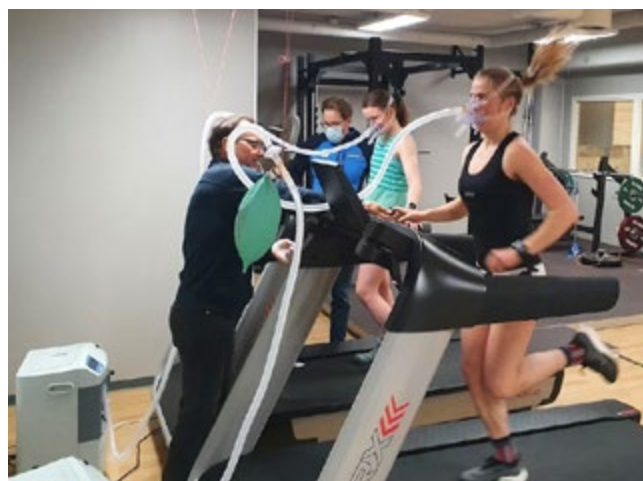


Figure 8.1. Hypoxia exercise at the Vuokatti testing environment.



Figure 8.2. A pole force sensor in the HYTELI project.

Cooperation with CEMIS

The goal of the CEMIS joint project HYTELI (Innovation platforms for well-being, health, and exercise), which ended in July 2021, was to develop technologically advanced innovation platforms and environments and to increase the international level of technological know-how and competitiveness in Kainuu. The starting point was to utilize the CEMIS consortium's interdisciplinary expertise in themes important to the region's livelihoods, such as preventive health care (health technology, nutritional health, smart home care) and Vuokatti's top sports environment and sports tourism.

In the project, innovation platforms were defined around the themes „Sport technology” and „Well-being and health technology”. After the definition was completed, competence area brochures were made of the innovation platforms to be used for networking and to market regional multidisciplinary measurement technology and research expertise, also for international contacts. The technological readiness and knowledge base of the innovation platforms were developed throughout the project, which enabled a faster response to the needs of the business field.

The Vuokatti unit acted as the coordinator of the project but also as the coordinator of sensor integrations and measurement technology development activities in Sport technology's innovation platforms work package. In addition to these, it participated in the development of ski competition simulations in work package 3.

Among the results of the exercise technology innovation platforms work package, the prototype of the trigger pressure measurement application (JYU & KAMK collaboration) and the development steps in sensor integrations can be highlighted in particular. Figure 8.2. shows a more advanced version of pole force sensor (VTT, JYU & KAMK collaboration).

The work done on ski competition simulations resulted in the implementation of the virtual environment of the sprint route of the World Championships in Oberstdorf and the virtual models of the sprint and biathlon routes of the Beijing Olympics (KAMK & JYU cooperation). The Beijing models were finalized as a purchase service acquired by the Olympic Committee from KAMK. The development of virtual models aroused interest in the media, and, e.g., the Finnish MTV3 news published a story on the topic on October 2, 2021, in the news broadcast.

Operations of CSC – IT Center for Science in Kajaani

CSC's operations in the CEMIS development program in 2021 took place within the framework of the HYTELI and TÄRY projects. A particular focus area has been clarifying sports data analytics needs and building national cooperation, for which CEMIS activities have created an excellent basis.

CSC – IT Center for Science is a national center for high-performance computing, data analytics, and information networks that offer services to universities, research institutes, the public sector, and companies. CSC is a non-profit company owned by the state and universities and managed by the Ministry of Education and Culture. CSC joined the CEMIS center in August 2016 and, since then, has focused on the application and dissemination of data analytics and artificial intelligence expertise in the CEMIS network.

The Kajaani site's growth in the High-Performance Computing field continued in 2021. The implementation project of the joint European LUMI supercomputer progressed to the first installations during the year. The LUMI data center was completed, and the first parts of the LUMI computer were installed and brought to customer use during the year. The supplier of the LUMI hardware is the respected supercomputer manufacturer HPE Cray. LUMI is one of three large systems acquired by the European cooperation body EuroHPC (<https://eurohpc-ju.europa.eu>).

CSC's national computing systems in Renforsin Ranta Business Park are located in the Varasto Building, where CSC's Kajaani office is also located. With the LUMI supercomputer (Figure 9.1.), the office expanded to the Rata Building, and the LUMI supercomputer itself is placed in the data center built inside the Kone Building. The significant increases in the computing capacity placed in Kajaani have also increased the personnel at CSC's Kajaani office and naturally aroused significant interest and cooperation potential worldwide. The Ministry of Economic Affairs and Employment of Finland also participated in the national funding of EuroHPC, which gave CSC a mandate to apply for extensive business use of the supercomputing environment. Business use started during 2021 using CSC's national systems and will expand to the LUMI environment next. CEMIS has been a valuable forum for building business cooperation.



Figure 9.1. The beginning of building the LUMI High-Performance Computer in the new data center

Machine vision applications for sports and exercise

As for CSC, the HYTELI project has focused on further developing image-based pose modeling (human pose estimation). Within the framework of the project, a master's thesis has been started, focusing primarily on collecting high-quality video reference material and teaching the neural network models used in pose modeling to be more suitable for skiing applications. To compile sufficiently comprehensive reference material, the work also develops a method for combining the 3D measurements of the motion capture system and the results of image-based pose modeling and for calibrating the used video camera.

Image-based pose modeling can also be applied to other uses that previously required separate motion capture equipment. In this project, the method has been developed for monitoring the test subject in the dynamic balance test developed in Vuokatti and in the ski station application for determining the position and center of mass of the skier's body, together with the automatic determination of the skier's pole angle (Figure 9.2.).

In 2021, data material for the training of the machine learning model had been compiled from the videos filmed in the skiing laboratory, and an algorithm has been developed with which the point cloud data produced by the VICON motion capture system can be used as training data for the machine learning model. A 3D

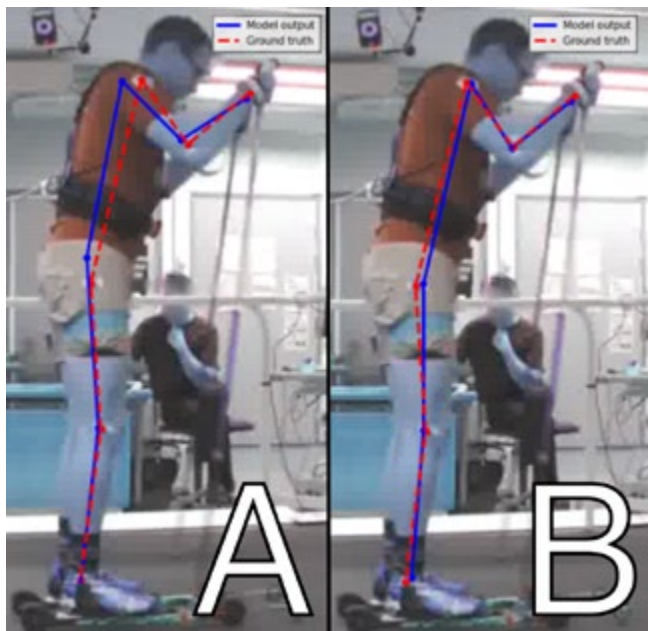


Figure 9.2. Comparing the performance of machine learning models with ground truth. Figure A shows the result produced by the publicly available AlphaPose model, while Figure B shows the effect produced by a model further trained on self-produced data.

camera calibration application has been developed to use video data. Using the data, different machine learning models have been trained, their performance in recognizing the skier's position has been compared, and a general-purpose position model has been applied.

Industrial operations supported by analytics

The TÄRY project develops know-how and training in industrial operation. The transition from traditional maintenance to continuous operation is a significant challenge in the industry, to which intelligent technology based on measurement and data analysis offers one answer.

In 2021, CSC supported KAMK's personnel in developing analytics expertise and building industrial cooperation. During the year, a collaboration with SSAB was launched. Experts from KAMK and CSC implemented a common data processing platform in CSC's cloud environment, preprocessed the received measurement data, and performed the first data analysis.

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CEMIS

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CEMIS is based in Kajaani and Sotkamo in Eastern Finland, far from the congestion and haste of major metropolitan centres. The region provides wonderful natural surroundings and splendid opportunities for leisure activities and hobbies as a counterweight to working. Please feel free to contact us by e-mailing info@cemis.fi if you are interested in working or studying at CEMIS..

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