

CEMIS Annual Report 2018



CEMIS

Centre for Measurement and Information Systems

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Chairmen's review

Developing new technologies, deploying them in production and generating expertise are increasingly important in the modern world. These are the key challenges that the CEMIS business model seeks to address.

By pooling expertise in research, development and innovation at universities and research institutes, CEMIS creates regional, national and international resources for action, boosting the regeneration, development and globalisation of Kainuu and facilitating the emergence of win-win networks. Such networks also bring added value to their parent organisations, and especially to the partners involved in projects.

The strength of CEMIS lies in retaining the flexibility to create the right operating models for future progress. CEMIS must find its own way and regenerate its own value added in every project undertaken. Its performance has been exemplary in this respect. The firm resolve of the parent organisations is an essential condition for building the importance of CEMIS and its future evolution.

We look forward to even more ambitious collaboration through CEMIS and its projects in years to come!



*Arto Maaninen
Vice-Rector for Co-operation
University of Oulu*



*Matti Sarén
President and CEO
Kajaani University of Applied Sciences*

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 members are the University of Oulu, the University of Jyväskylä, the Technical Research Centre of Finland (VTT), Kajaani University of Applied Sciences, and CSC – IT Center for Science.

CEMIS comprises the University of Oulu Measurement 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 members 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 regards CEMIS as its principal vehicle for co-operation between universities and research institutes. For the University of Jyväskylä, CSC and VTT, CEMIS is a form of regional co-operation.

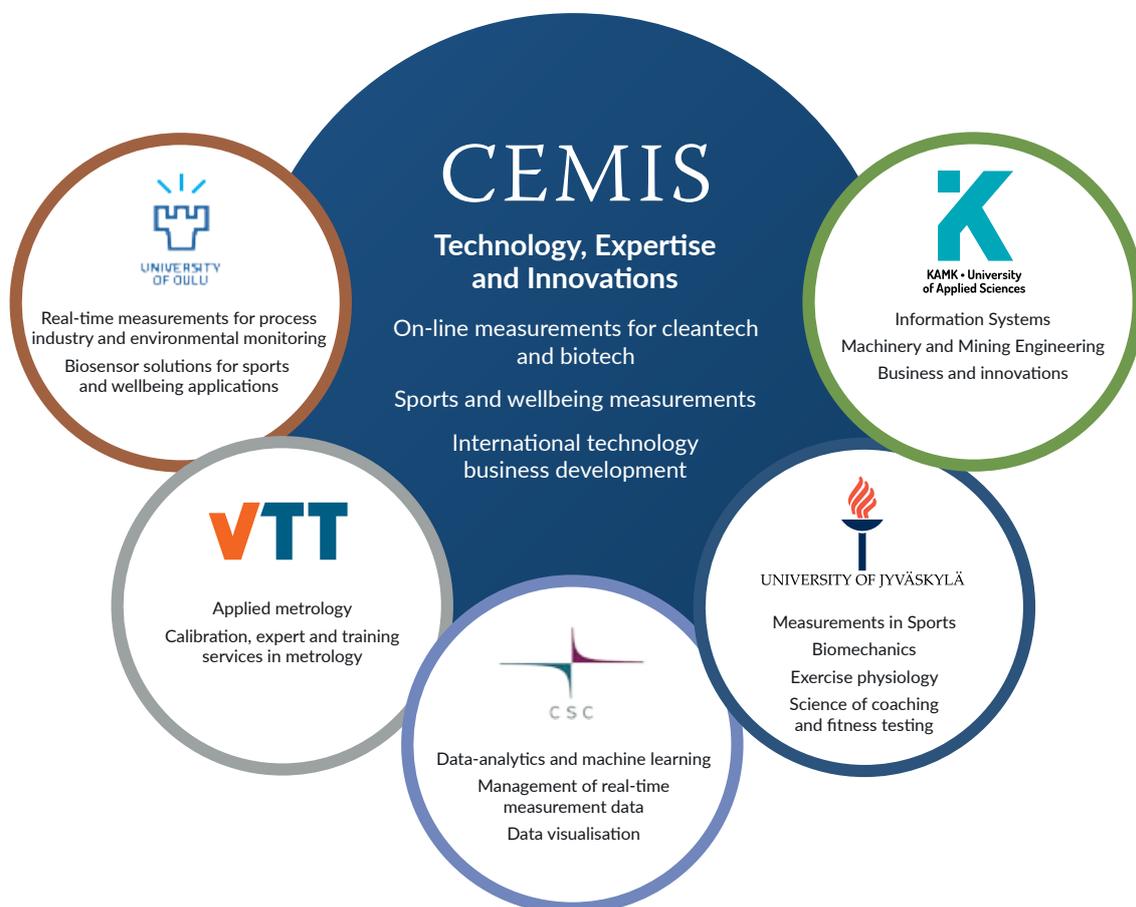


Figure 2.1. CEMIS focus areas and member organisation with their main expertise.

Collaboration between the CEMIS members includes a joint strategy and management group (Figure 2.2), co-operation in RDI co-ordination of project activities, joint marketing and PR, and business development, co-operation in prototypes, developing joint facilities and environments, and cooperation in education.

Reliability is a key value of CEMIS. The CEMIS members seek to be trusted partners and contributors to their parent organisations, to one another, to their region, to their customers and to their other partners. CEMIS also ensures the reliability of the measurement technology solutions CEMIS develops, and of the measurement results that they provide.

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

1. On-line measurement solutions to meet the needs of process industries, and especially of the bioeconomy, mining and environmental monitoring sectors (Cleantech and Biotech)
2. Measurement and testing solutions for sports, wellness and healthcare applications using sensor solutions, and 3D and VR technology-based game and simulator solutions (Sports and Wellbeing)
3. Developing international technology business based on the technological expertise of CEMIS and partner companies (International Technology Business)

CEMIS provides reliable measurement 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 seeks to bring about internationally significant expertise, and new technology and business operations.

CEMIS provides measurement and information systems, new business and industry excellence for enterprises and research institutes that are developing and applying new technology by providing R&D services and higher education in an innovative and international environment. The Centre provides an innovative and international working environment for aspiring researchers and specialists, and an inspiring learning environment for students seeking to qualify for future specialist positions.

Its mission is to make its education and research activities in the field of measurement and information systems increasingly attractive,



Figure 2.2. CEMIS Strategy Group for 2018. Pictured from left to right: Development Director Mikko Keränen (KAMK), Director Mikko Kerttula (CEMIS), Senior Planning Officer Toivo Takala (University of Jyväskylä), Director of Research Services Pekka Lehtovuori (CSC), Professor Janne Avela (University of Jyväskylä), Mayor Mika Kilpeläinen (municipality of Sotkamo), Development Director Risto Hämäläinen (City of Kajaani), Director, Professor Vesa Virtanen (Kajaani University Centre), Vice-Rector for Co-operation Arto Maaninen (University of Oulu), and Vice President Martti Heinonen (VTT MIKES). The members CEO Matti Sarén (KAMK) and Mayor Jari Tolonen (City of Kajaani) are missing from the picture.

competitive and effective. To achieve these aims, CEMIS has set quantitative performance targets for its operations in R&D, education and innovation, both for the Centre as a whole and for each individual member.

The CEMIS Development Programme specifying measures to enhance operational co-ordination, collaboration and division of duties, use of shared resources and visibility is a key tool in the work of CEMIS. With an annual budget of approximately EUR 1.7 million financed

mainly through ESF and ERDF programs in Northern and Eastern Finland, the fourth two-year CEMIS Development Programme period ended in 2018. The total annual funding of CEMIS is more than EUR 12.5 million, consisting of self-financing by the members, regional development funding (including the CEMIS Development Programme), and competitively tendered external financing. CEMIS employs nearly 100 specialists in measurement and information systems.

Activity priorities of CEMIS:



CLEANTECH & BIOTECH

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

Director's review

The eighth full year of CEMIS operations continued in line with the Centre's strategy and operating plan. An enlargement of the Centre's business partnership base was one positive reflection of the general economic upturn both globally and regionally. Both funding applications and other forms of collaboration continued to stress internationalisation. By strengthening funding with new funding possibilities, like with EU Horizon 2020 calls, CEMIS prepares for potential risks arising from changes in Finland's regional development policy and EU regional development funding after 2020. Some regionally significant progress has been made, particularly in the Kajaani data ecosystem with the support of CEMIS operators CSC and KAMK. The role of Kajaani as a leading data ecosystem in Finland has been boosted in particular by a 33-million-euro Finnish government investment in new high-performance computing infrastructure in Kajaani, and by KAMK's education investments in data analytics and high-performance computing.

The strategy, operating plan and joint collaboration agreement of CEMIS were updated in late 2016, and the Centre's fourth development programme for 2017-2018 was also planned at this time. With minor updates, these results have clearly still continued to guide operations in 2018.

CEMIS operates and improves its work in accordance with the performance objectives specified in the Centre's operating plan, assessing outcomes in three categories: education, R&D and innovation activities. CEMIS realised these outcomes with a staff of nearly 100 people in 2018.

The publishing rate of CEMIS remained strong over the year, with the release of 24 peer-reviewed scientific articles and 23 conference and professional publications. Two Doctoral degrees, five Master's degrees, eight university of applied sciences Master's degrees and 112 university of applied sciences Bachelor's degrees were conferred at CEMIS in 2018.

CEMIS ran an average of approximately 50 ongoing R&D projects in 2018. There were more than 70 projects over the year as a whole. The fourth two-year CEMIS Development Programme for 2017-2018 continued with four projects, three of which ended at the end of



"CEMIS focused on international co-operation in 2018. I firmly believe that CEMIS also has realistic prospects of selling its own competencies and those of its member organisations internationally, thereby further strengthening the vitality and technological expertise of the Kainuu Region."

Mikko Kerttula, Director, CEMIS

2018. The more detailed content of the programme, its operations and the results achieved will be described later in a separate section of this annual report. CEMIS was also involved in ten international projects with a funding share of EUR 0.3 million. Regional funding from the Regional Council of Kainuu or the ELY, Centre for Economic Development, Transport and the Environment was EUR 3.7 million. The aims of these projects included developing new solutions for water treatment, finding ways of monitoring metal concentrations in industrial wastewater, developing process analysers for manufacturing bioethanol, recycling and repurposing industrial sidestreams, using natural raw ingredients in the food supplements and food industry,

athlete testing and coaching, measurement solutions for biathlon, biosensors for healthcare, data analytic solutions for enterprises, applying VR/AR technology for digitising the mining industry, methods for torque measurement standards, and metrology for multiphase flows.

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. Five new commercially applied inventions were developed and two new companies were founded within CEMIS in 2018.



The Measurement Technology Unit of the University of Oulu (MITY) continued its strong trend of scientific and conference publishing. Three technologies were also commercialised and one new enterprise was founded on the basis of the unit's research.



Kajaani University of Applied Sciences strengthened its international operations with a significant boost in preparing new projects, particularly under the EU Horizon 2020 research programme. A record number of 120 students graduated from programmes in CEMIS fields of expertise. Demand for VR and 3D skills in particular remained high in service business operations. One new technology solution was also commercialised.



The Vuokatti sports technology unit of the University of Jyväskylä substantially strengthened international researcher and specialist exchanges, especially towards China. A new large ski treadmill was acquired for Vuokatti, providing

better conditions for laboratory research into various skiing techniques. The Master's degree programme in Sports Technology arranged new enrolments in 2018 and the doctoral school continued active operations. The unit also continued its strong publishing trend.



The level of service sales to industry at the **VTT Kajaani unit** remained stable. Active participation has similarly continued in international research through European Horizon 2020 EMPIR (European Metrology Program for Innovation and Research) projects, and a new enterprise was established based on the unit's research.



CSC - IT Centre for Science has brought significant added value to CEMIS Development Programme projects and businesses in the region with its expertise in data management, data analytics and artificial intelligence. In particular, a new Data Analytics Accelerator project launched by CSC has solidified the offering of expertise to Kainuu enterprises. The Ministry of Education and Culture confirmed one important reinforcement of the Kajaani data ecosystem in January 2018 with a data management and computing infrastructure investment, mostly to be implemented at the CSC Kajaani Data Centre.



Figure 3.1. CEMIS participated in an export promotion delegation to China by Sampo Terho (pictured middle), Minister for European Affairs, Culture and Sport in March 2018. The CEMIS representatives on the trip were Director Mikko Kerttula and Head of CEMIS Business Development (CBD) Dr. Anas Al Natsheh.

Total funding for the Centre in 2018 reached a record EUR 12.6 million (+ 10%), divided as follows: international funding of EUR 0.3 million (-49%), national funding of EUR 1.6 million (+39%), private enterprise funding of EUR 0.9 million (-2%), regional funding of EUR 3.7 million (+ 14%), and self-financing of EUR 6.2 million (+ 10%). The Centre is seeking to increase international funding to EUR 1.15 million, reduce national funding to EUR 1.4 million, and boost business funding to EUR 1.2 million by the year 2021.

The qualitative goals of CEMIS for 2017-2018 were to generate new technology business operations and achieve a clear increase in international R&D co-operation and funding. New business was directly created in 2018 through the foregoing two new enterprises founded by staff and students of CEMIS operators. CEMIS has worked to boost international funding through the CEMIS EU Project Team, which was involved in preparing ten project applications during 2018 for the final period of the Horizon 2020 research programme in 2018-2020. The Faster project application (First responder Advanced technologies for Safe and efficient Emergency Response, <https://www.faster-project.eu>) prepared by KAMK secured a favourable funding decision at the end of the year.

Active international co-operation has continued for CEMIS both at European level and in a broader global context. Co-operation in Europe includes work with the Universities of Salzburg, Ljubljana, Gothenburg and Turin. CEMIS has also continued or initiated co-operation in South America (Peru, Chile and Brazil) and in Kazakhstan, China (Beijing Sport University and the Chinese Ski Federation) and Vietnam.

In the context of European Union co-operation, CEMIS contributed to implementation of the EU Smart Specialisation Platform (<http://s3platform.jrc.ec.europa.eu>) by the ClusSport consortium, which operates within a smart specialisation strategy concerning the thematic field of sport (<https://s3platform.jrc.ec.europa.eu/sport>). The Centre has also been involved in regionally crafting the measures and objectives of the smart specialisation strategy with the Regional Council of Kainuu. CEMIS has served in a specialist capacity in the Regions in Industrial Transition pilot project (ELMO) financed by the European Commission, in which the regional authorities of Eastern and Northern Savonia are seeking new inter-regional approaches to support the business growth in the region.

China was a particular focus of international co-operation efforts in 2018. The potential for collaboration was widely explored in several fields, including winter sports coaching solutions, water treatment and monitoring, VR applications, educational collaboration, and health and elderly care. CEMIS representatives participated in two ministerial delegation visits to China. An export promotion trip in March led by Sampo Terho, Minister for European Affairs, Culture and Sports, focused on exports and co-operation in the field of winter sports expertise (Figure 3.1). CEMIS expertise was presented to Chinese Minister of Water Resources E. Jingping at a November meeting of the China Europe Water Platform (CEWP) in Beijing. The delegation was organised by the Ministry of Agriculture and Forestry Finland represented by Anne-Mari Virolainen, Minister for Foreign Trade and Development. A visit by Chinese Sports Minister Gou Zhongwen to Vuokatti in May was also an important event for co-operation with China. In May I also represented CEMIS as part of a Kajaani Town

Delegation to Jiujiang, the twin city of Kajaani in China.

Several concrete follow-up actions have been launched in China as a result of these efforts. The most important of these are a winter sports expertise project proposal of the University of Jyväskylä, preparation of KAMK education co-operation, and preparation of a pilot project of CEMIS spinoff company for water monitoring in China. The co-operation has led to the conclusion of several letters of intent (LOI) in China, including a deal with the Nanjing Software Valley business park. In spring 2018 CEMIS became a member of the China-Europe Health & Sports Council (CEHSC, <https://www.cehsc.eu>), and has thereby been able to meet promising partner candidates in China, both in the private and government sectors.

In line 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. Even though operations have a strong regional policy focus, the objectives and results of the centre can only be achieved through international standards of excellence and with the aid of international co-operation and markets. CEMIS will accordingly continue to invest strongly in international operations in coming years.

Besides its regional mission, CEMIS is also responsible for ensuring the vitality and finances of the Centre's member organisations. CEMIS will accordingly also focus on strengthening the finances of its members by developing the service business and commercialising research findings. The three focus areas of CEMIS – Cleantech & Biotech, Sports & Wellbeing, and developing the international technology business – also give the organisation promising opportunities for exploiting its expertise internationally. I firmly believe that CEMIS also has realistic prospects of selling its own competencies and those of its members internationally, thereby further strengthening the vitality and technological expertise of the Kainuu Region.

Operating conditions seem favourable for CEMIS in coming years. A large number of project applications were prepared during 2018, and the results of this work will be realised in 2019. The fifth CEMIS Development Programme for 2019-2020 was also planned by the end of 2018, and was launched with five new projects in early 2019. The operations of the centre in 2019-2020 will largely continue on the basis of its current strategy and operating plan, subject to minor updates. Some more major changes in operating conditions are expected after 2020 with the start of the new 2021-2027 funding period both for nationally managed EU regional funding and the new EU research framework programme (Horizon Europe). The strategy and operating plan of CEMIS will be updated in 2020 to adapt to ever-changing operating conditions, as influenced by regional objectives, the new EU funding period, global technology and research trends, and the independent objectives of CEMIS members.



Mikko Kerttula, Director, CEMIS

CEMIS 2018 in figures



NEW SPINOFF
COMPANIES



COMMERCIALY
APPLIED INVENTIONS



INTERNATIONAL
PROJECTS



EUR 0.4 MILLION IN
R&D SERVICE SALES



PEER-REVIEWED
SCIENTIFIC
PUBLICATIONS



DOCTORAL DEGREES
AWARDED

TOTAL FUNDING
OF THE CENTER, EUR

12.6
MILLION +10%

INTERNATIONAL
FUNDING, EUR

0.3
MILLION -49%

NATIONAL FUNDING, EUR

1.6
MILLION +39%

PRIVATE ENTERPRISE
FUNDING, EUR

1.0
MILLION -2%

REGIONAL FUNDING, EUR

3.7
MILLION +14%

SELF-FINANCING, EUR

6.2
MILLION +10%

PERCENTAGES INDICATE YEAR-ON-YEAR CHANGE
COMPARED TO 2017.

CEMIS Development Programme 2017-2018

The development programmes of CEMIS are a key operational tool for achieving the Centre's objectives and realising co-operation between the CEMIS members. Launched in early 2017, the Centre's fourth two-year development programme concluded at the end of 2018.

The development programme was prepared jointly between the CEMIS members, local businesses and regional development financiers, with a view to enabling the Centre to achieve its qualitative objectives of improving the attractiveness, competitiveness and impact of its education and research work in the fields of measurement and information systems. The impact goals of the programme recognised national strategies, for example through Finnish government flagship projects, the programmes of EU Regional Development Funds, and the Implementation Plan for the Kainuu Regional Program (TOPSU 2017-2018).

The two-year programme was mainly funded by the ERDF programme for Eastern and Northern Finland, with a total budget of approximately EUR 3.52 million. A steering group comprising representatives of CEMIS members, financiers and businesses guides the programme and its projects. The programme and its projects were divided into three development packages: new technologies for sustainable biofuels and mining (the BIOMIT and KAIMIT projects), new sport and wellbeing technologies and services (the LIIKUTPA project), and international R&D, technology transfer services and demonstrations (the KANTELI project). The programme implemented joint technology development projects in key technology and application fields of importance to the business development of local enterprises, developed collaboration in realising hardware solutions, completed marketing and PR measures related to outcomes of the programme, and promoted commercial exploitation of R&D project findings.

One quantitative programme objective was to increase the Centre's industry and international funding substantially compared to the previous 2015-2016 programme. A further aim was to establish at least 6 new enterprises and commercialise at least 4 technologies developed at CEMIS. The programme successfully boosted corporate funding, securing a 15 per cent increase and doubling CEMIS partner service sales (including custom R&D services) compared to the previous programme. Growth in international funding was not yet reflected in the results for 2018, but a record number of international funding applications were submitted, and the earliest outcomes of this work will only become evident in the figures for projects

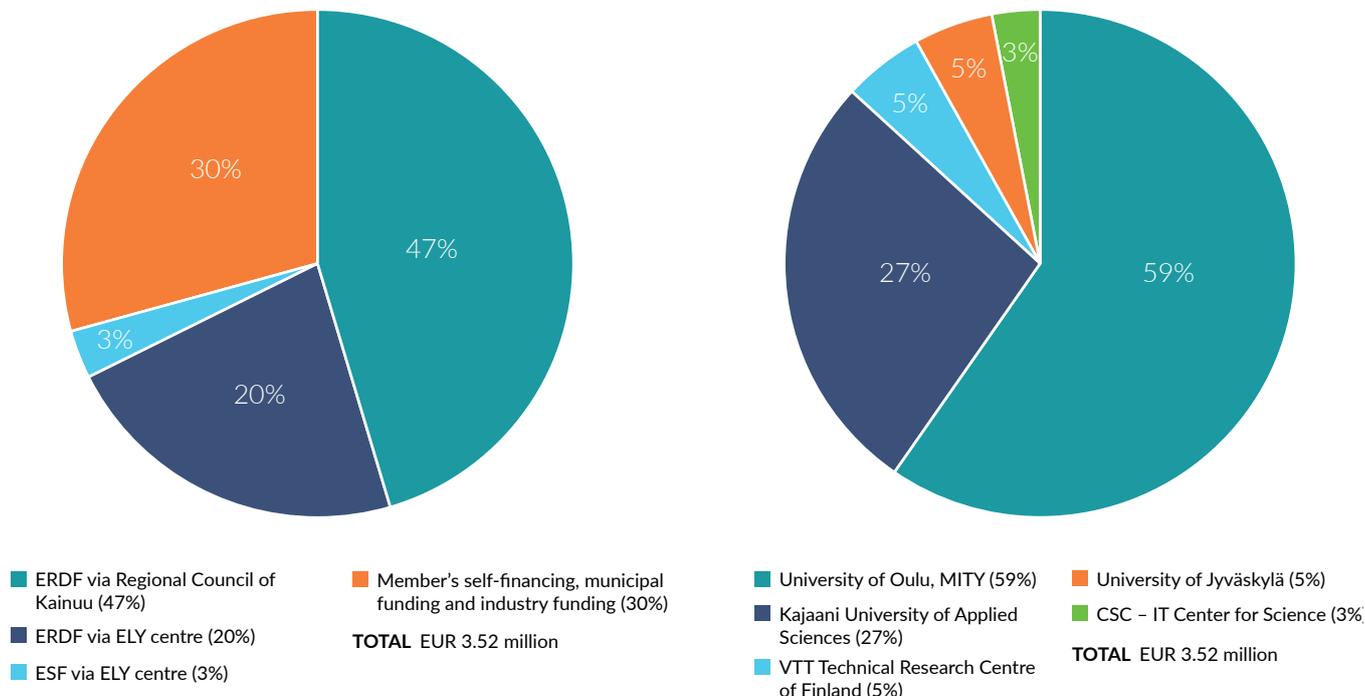
launched during the current year. The objectives for innovation were exceeded insofar as 7 new enterprises were set up and 7 developed technologies were commercialised through the programme.

The explicit impact goals of the CEMIS programme are as follows:

1. To reduce industrial CO₂ emissions by developing solutions to enhance bioenergy generating and the mining industry
2. To reduce environmental pollution by improving water management in process industries and mining
3. To establish new spin-off businesses and generating new business for existing companies
4. To increase international business opportunities for technology companies in the Kainuu region
5. To maintain the status of Kajaani as a centre of expertise in measurement technology
6. To reinforce the status of Vuokatti as an international training, coaching and research centre for skiing sports
7. To strengthen the position of Kajaani and Sotkamo as an expertise cluster in the field of wellbeing measurement technology

All of these objectives were achieved or well supported as a result of programme projects and co-operation between the CEMIS members. Objectives 1 and 2 related to technology solutions were directly achieved through BIOMIT and KAIMIT R&D project work, while objectives 3 and 4 relating to innovation work were a joint outcome of all projects. Technology enterprises were supported through market inroads in China and South America under the KANTELI project. Regional objectives 6 and 7 were specifically supported through the LIIKUTPA project and general objective 5 to strengthen the status of Kajaani as a centre of expertise in measuring technology was supported throughout the program and through CEMIS activities.

Three of the four development programme projects were completed in 2018, with the timetable for one project extended into 2019.



ELY-Centre: The Centre for Economic Development, Transport and the Environment for Northern Ostrobothnia

Figure 4.1. Distribution of CEMIS Development Programme financing in 2017-2018 by member and funding source.

1. *New Processes and Measurements for the Bioeconomy and Mining Industry (BIOMIT)*

This project sought to reduce industrial carbon dioxide emissions by developing measurement solutions to optimise bioenergy generating and mining industry processes. It also sought to reduce the environmental impacts of industry by developing solutions for water management in the process and mining industries, and new methods for efficiently using biomass and sidestreams in Kainuu according to the principles of a circular economy. The project was prepared in close partnership with important enterprises operating in Kainuu (Terrafame Ltd., St1 Group, Valmet Automation Ltd., KaiCell Fibers Ltd.) and a major regional SME group (Aquaminerals Ltd., Prometec Ltd., Teollisuustaito Ltd., Meoline Ltd., Sotkamo Silver Ltd., Mondo Minerals B.V. Branch Finland, Nordic Biorefinery Ltd., Koneistamo Alm Ltd., Kuhmo Ltd., Kajaaniwood Ltd., Infrasuunnittelu Ltd., EHP Environment Ltd., Otanmäki Mine Ltd., Tieto-Oskari Ltd.). Some of these enterprises are also committed to funding the project and serving as technology testers for innovations developed during the project.

The project measures were divided into four work packages:

1. Reinforcing and developing digital modelling and simulation skills
2. Real-time monitoring and competence development
3. Piloting measurement solutions
4. Predictive measurement solutions, and control of measurement data and its reliability
5. Administration, communication and preparation for commercialisation.

The total project budget of EUR 924,531 was mainly channelled through the Regional Council of Kainuu (ERDF funding). The project leader is the Measurement Technology Research Unit (MITY) at the University of Oulu, and the other participants are VTT Technical Research Centre of Finland and CSC - IT Center for Science. The project was completed at the end of 2018.

Project results

The project increased the expertise of VTT and University of Oulu units with respect to modelling and simulating complex systems and phenomena using COMSOL Multiphysics and OpenFOAM software. This expertise was applied in such fields as research into electrical conductivity and electrochemical sensors, and in determining mass properties in flows. Businesses in the region also need this expertise, and the project successfully informed them of the new tools and the opportunities that they provide.

Another significant project package arranged technology demonstrations for enterprises. Two new technologies were developed and piloted in the field of real-time measurement expertise: NIR measurement for managing and optimising difficult industrial processes, and real-time assays of arsenic. Direct real-time continuous spectrum measurement was developed using NIR technology (Near-Infrared) with industrial samples under laboratory conditions. A new type of NIR probe was also designed, built and tested for difficult samples and tough conditions. A new, independently and continuously operating NIR measuring instrument was built into a process sidestream based on laboratory tests. This instrument performed successfully in field measurement cycles in the paper, pulp and mining industries under demanding process conditions and almost entirely under remote control (Figure 4.2). In electrochemical



Figure 4.2. Industrial trials of a real-time NIR measuring device developed as part of the BIOMIT project.

assays of arsenic various buffer solutions, such as phosphate, acetate, potassium nitrate and hydrochloric acid, were applied and sensor surfaces were developed to improve the sensitivity, and laboratory tests on arsenic reference samples were conducted.

Supercritical CO₂ fluid extraction (SFE) was developed and tested for use in processing raw pinewood sidestream samples. Analytical methods were further developed for sidestream extract samples using gas chromatography techniques (GC-MSD and GC-FID). It was concluded that SFE is an interesting technology for processing forest industry sidestreams (Figure 4.3), providing a basis for analysing and further developing the analysis of raw material extractives. Trials demonstrated the functionality of the process, leading to the establishment of project to test it on a larger scale funded by Business Finland and assisted by six enterprises.

CSC – IT Center for Science conducted a data analytics consultation in the context of the BIOMIT project, exploring the prospects for



Figure 4.3. The BIOMIT project developed the extraction of biochemicals from pine branches arising as sidestreams of the forest industry.

identifying metal by-products in data collected by the mining industry, and thereby significantly increasing the value of data collection. CSC also conducted two NIR sensor data analyses with a view to reducing the number and cost of measurements required - 1) A comparative analysis of two measurement technology methods with a view to using the more appropriate method for various purposes, and 2) Cross-correlation analysis of delayed connections between lines (Figure 4.4) with a view to understanding how a change visible on one line propagates to other lines. Data analytical methods enable commensurable adaptation of various measurement results and a resolution of data disruptions to enhance visibility of the basic phenomena. More advanced data-driven results would require more extensive data collection. A summary report of the analyses and a recommendation for further development were prepared.

Two new start-up enterprises are planned to commercialise the technologies developed in the project.

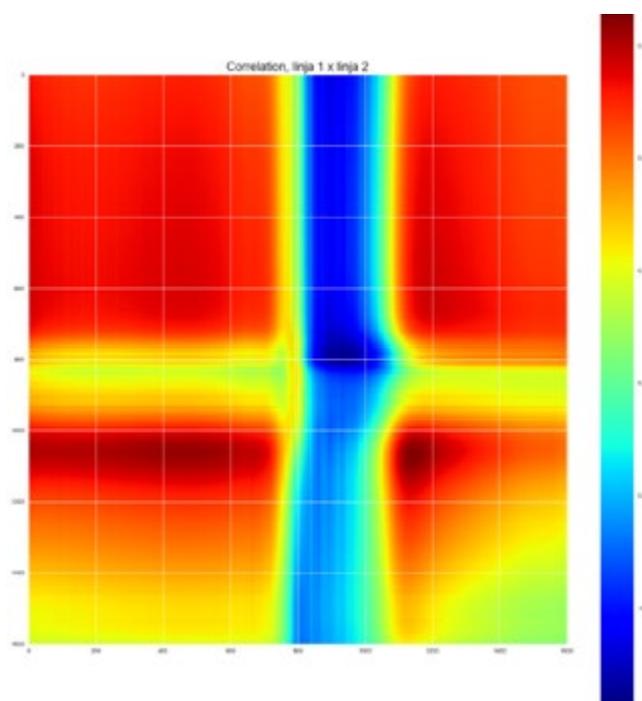


Figure 4.4. Visualisation of cross-correlation analysis of NIR sensor data from two-line wavelength data. Based on the analysis, it was possible to determine the delay between the lines.

2. Novel Environmental Measurements for Mining and Other Industry Discharge Waters (KAIMIT)

The KAIMIT project is continuing in 2019 with a view to realising effective new measurement methods for monitoring sulfate and phosphate concentrations in industrial effluent. There are currently no cost-effective and reliable methods on the market for monitoring low sulfate and phosphate concentrations. This project is developing approaches based on electrochemical and optical methods, and building demonstration hardware for field measurements that will be piloted at industrial sites. It also seeks to increase communication between equipment manufacturers, system integrators, end-

customers and public authorities concerning the prospects for real-time measurements.

Implementation of the project involves five work packages:

1. Real-time monitoring and competence development
2. Piloting measurement solutions at fixed measuring points
3. Piloting measurement solutions on a waterborne vessel
4. Preparing the commercialisation of developed measuring devices, measuring solutions and modified sensors
5. Administration and Communication.

The project seeks to implement new technological solutions for subsequent commercialisation through corporate R&D projects. Some 2 to 3 technologies will be developed and piloted for real-time measurement of sulfate and phosphate concentrations in industrial effluent. These technologies may be used to build systems for efficiently monitoring watercourses, optimising treatment processes and preventing environmental pollution.

The total project budget of EUR 399,707 is mainly ERDF funding channelled through the Northern Ostrobothnia Centre for Economic Development, Transport and the Environment (ELY Centre). Project implementation is a responsibility of the MITY at the University of Oulu.

Project results in 2018

The multiple optical sulfate measurement approach was tested on natural water samples collected at various depths from several lakes in the Kainuu region. Good results were achieved using multivariate modelling. The sulfate assay was also tested by electrochemical means (impedance method). The tests used lead-modified electrodes with a good response to standard samples/sulfate concentrations. The effect of various interfering substances was also studied. With respect to phosphate, a report was prepared on phosphorus chemistry and associated measurements. The effectiveness of a capillary electrophoresis (CE) method for sulfate reference determination was confirmed. Refractive index and transmission spectral measurements (Figure 4.5) were added to the measuring hardware of the MITY water measuring vessel, enabling onboard field measurements.

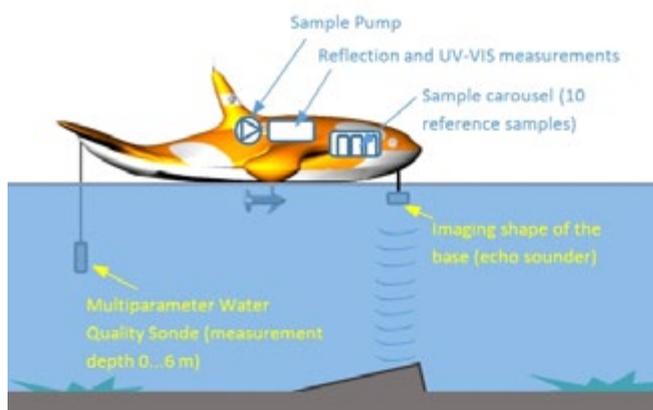


Figure 4.5. The KAIMIT project used the MITY water measurement vessel for sample collection and measuring.

3. New Sport and Wellbeing Technologies and Services (LIKUTPA)

Completed at the end of 2018, the LIKUTPA project was implemented by all five CEMIS members - the University of Jyväskylä (JYU) and the University of Oulu (MITY), Kajaani University of Applied Sciences (KAMK), VTT MIKES Metrology and CSC - IT Center for Science Ltd., with JYU serving as project co-ordinator.

LIKUTPA sought to produce measurement solutions that would allow people to self-monitor their health and wellbeing, facilitating the evolution of public health care towards remote and self-diagnostics, and boosting top-level sport and new sport technology business operations in Finland. Using sensor, game and simulator solutions, the project applied measurement and testing approaches in sports, wellness and health care applications. Its main goals were to develop and pilot modern demand-driven applications, and to create a knowledge base and capacities that would enable commercialisation of developed technologies and boost international co-operation.

The total project budget of EUR 1,431,000 was mainly ERDF funding channelled through the Regional Council of Kainuu.

The project work packages were:

1. Sports technology (intelligent ski sport equipment) and advanced athlete testing environments
2. Non-invasive sensors and measurements of wellness: smart homecare and wellbeing, sport applications, development of technology and systems, and sensitive health data
3. Serious games and virtual environments: real video as part of virtual environment training, and big data analytics
4. Business development, and project and business co-operation
5. Co-ordination and communication.

Project results

The main results of the project by work package (WP) were:

WP1: Sports technology and advanced athlete testing environments (JYU, VTT, KAMK and CSC)

Replicable prototypes of sensor integrations for ski poles (Figure 4.6) and biathlon rifles proved effective. The developed prototypes may be used as such in sports research and in future athlete testing services. The work package also implemented a plan for 3D force measurement with resistance strain gauge sensors for roller skis. Development work began by measuring one direction of force (the vertical), with the sensor ready for testing at the end of the project.

Ski equipment testing used the new force sensor to broaden ski tester functionality. The new force sensor allows both free ski gliding tests and traditional ski kick measurements. The tester was used in Master's thesis work on sports technology, focusing on comparing the grip and gliding properties of traditional skis under varying conditions on natural snow and in the laboratory. Details from the Master's thesis were communicated to the relevant sports federations. A

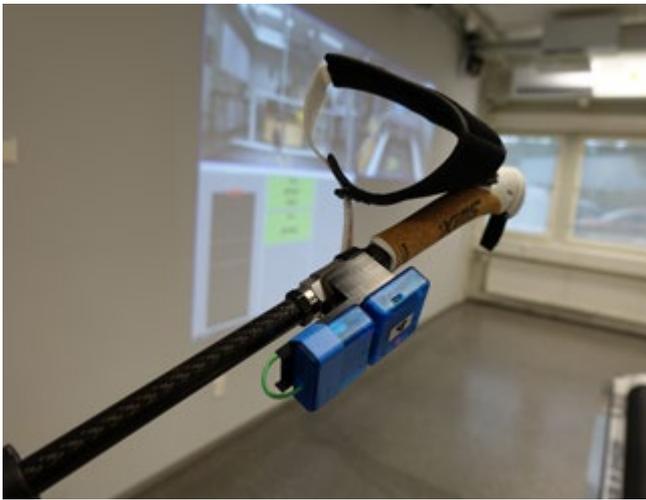


Figure 4.6. Prototype sensing using a piezoelectric sensor to measure ski pole forces, with the force sensor fastened between the pole and the handle.

machine vision application was developed for athlete testing use in ski coaching. The goal was automatic calculation of pole angles during competition, with multiple angle calculation trials made in various applications, such as shooting in the prone position, roller skiing on a ski treadmill and dynamic balance. A single-angle calculation application was already available for research purposes during the project.

WP2: Non-invasive sensors and wellbeing measurements (MITY, KAMK and CSC)

Work on non-invasive measurements focused on developing a newer and more compact version of the biosensor reading device - a system comprising biosensor strips and a small mobile reader

was developed into a functional unit that may also incorporate new sensor measurements in future. Work related to insulin focused on sensitising measurements, with significant progress achieved. The sensitivity of measurement suffices to detect even the smallest salivary concentrations and to determine normal concentrations. Studies of stress markers involved measuring the stress hormone cortisol, with the manuscript for an article on work to develop an immunosensor for laboratory use completed with a view to publication in *Talanta*, a leading international journal in the field of sensors. Conversion of cortisol assays to the same kind of quick test format used for determining insulin levels was tested in the early stages of the project before resources were eventually diverted to concentrate on improving insulin assays. Pulsed potential differential label-free biosensing (PUPOD Sensing) was developed as a new innovation in sensor technology.

The principal new enhancements achieved during the project were quality specifications that led to business collaboration and new products in service analytics. The work package commercialised three new service analytics products capable of demonstrating that health technology products are free of harmful impurities (one assay for harmful microbial compounds and two for harmful enzyme activities), and reformulated laboratory documentation and reporting practices as part of a new initiative for improving quality assays.

A project segment focusing on smart homecare gave rise to two demonstration systems: multi-parameter NEWS measurement (assessing the need for treatment) and a single sensor measurement application suitable for self-measurement. The solution was intended to comprise the following elements: 1) sensors suitable for primarily wireless self-measurement, 2) secure wireless data transmission to

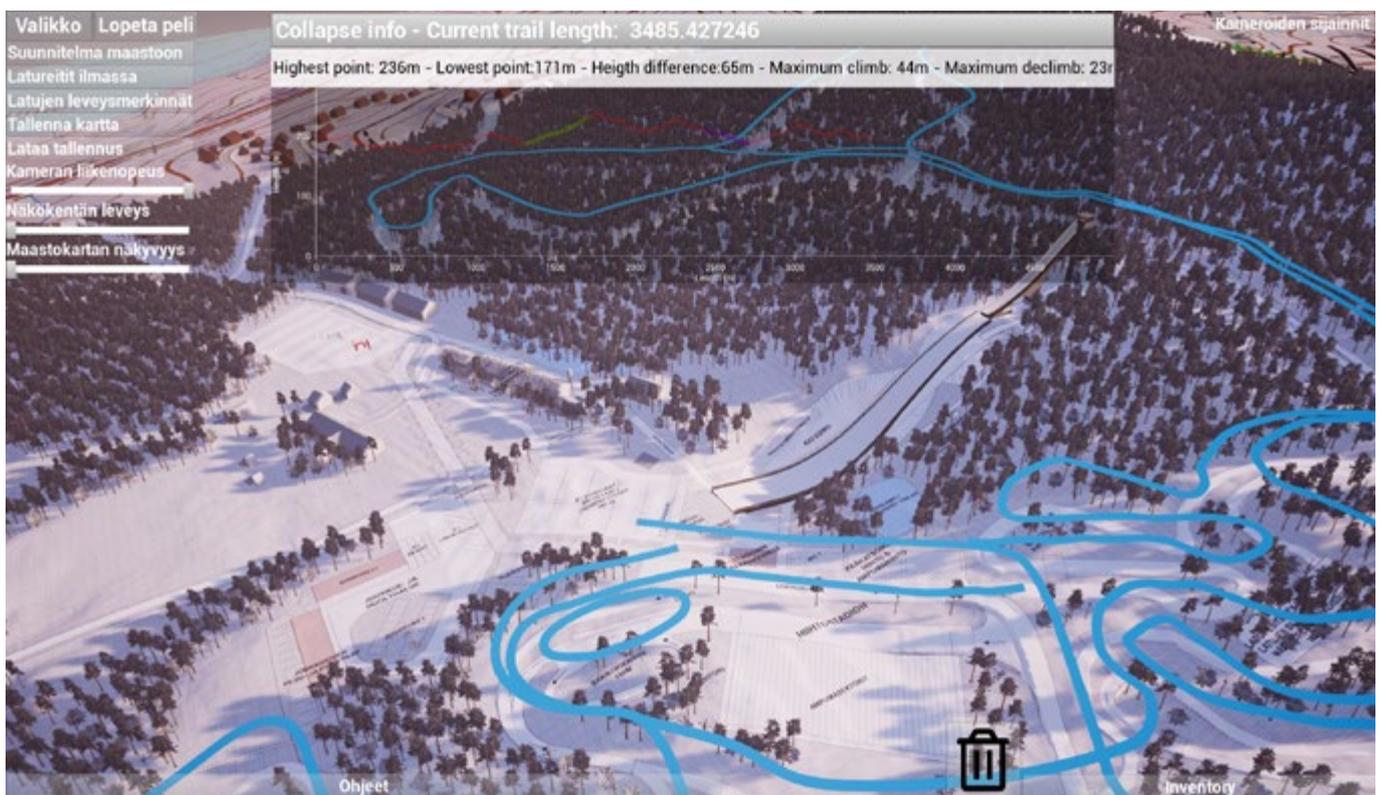


Figure 4.7. The LIIKUTPA project developed 3D modelling technology to support the design of sports and event areas.

a data collection unit (mobile terminal), 3) secure data transmission to a cloud service and healthcare information system (test server), and 4) visualization of processed information for users at various levels (nurse, doctor, citizen). Both solutions were regularly piloted during the project in the DIGIOS treatment and healthcare learning environment, and further developed based on the feedback received.

Work package activities related to sensitive health data included a seminar in Kajaani on cloud processing of sensitive data, in which CEMIS staff and regional business partners were involved. The work package also included a study of sensitive data processing in big data environments.

WP3: Serious games and virtual environments (KAMK, JYU and CSC)

The goal of simulating a real environment for athlete testing was achieved in the form of a simulated environment for the PyeongChang 2018 Olympic Sprint Race. The project resulted in a functional training environment based on real video footage and a route profile with authentic ski treadmill speed control, which was piloted with sprint skiers from the Finnish national team. The same development platform was also used for simulating the 2019 World Championship competition track in Seefeld. The project segment also developed a prototype sports and event area design tool for flexible modelling of realistic 3D environments (Figure 4.7). Several modern modelling methods and game-like features were used for implementing the solution: photogrammetry-based 3D models, laser-scanned terrain data, digital map data, VR functionalities, movement modes and field design.

WP4: Business development, project and corporate co-operation (JYU, MITY, KAMK, VTT and CSC)

This work package promoted the dissemination and impact of project findings, including through national (25) and international (12) project preparations, and participation in sports and wellness events in Finland and abroad. A total of 33 partnership negotiations were initiated over the course of the project with businesses operating in the fields of sports or wellness technology, virtual or augmented reality, 3D modelling or smart homecare and wellness measurement solutions, both within and beyond the Kainuu region. The project studied the commercialisation of health fitness technology and biosensor innovations through a start-up enterprise or licensing, together with the market in the sector and funding instruments. The project also included collaboration between MITY and the Department of Electrical Engineering at the University of Oulu - with university researchers working at both locations to prepare projects in support of healthcare in sparsely populated areas, especially access to diagnostics and treatment. Co-operation with the CEMIS Development Programme KANTELI project included a market study on Coachtech Coaching Feedback System. This inter-project collaboration also included designing and implementing an optional business studies package for the University of Jyväskylä Master's degree programme in sports technology. A pilot course was completed in May-June 2018, with favourable feedback received from Master's degree students in sports technology.

The project gave rise to a total of 13 new business partnership, and separate RDI work was launched with four of these. Five new innovation platforms were developed and used in business collaboration to pilot a total of 12 products or services. Three new service products were developed (related to MITY quality specifications) with the creation of one half-time job (0.5 person-years). The results served as a basis for seeking national project funding of EUR 1.4 million and industry funding of EUR 0.2 million. One international peer-reviewed academic publication and doctoral dissertation was prepared on the basis of biosensor measurement development measures.

4. *International Technology Business (KANTELI)*

The KANTELI project developed an operating model seeking to effectively promote the establishment of international business, primarily in Kainuu and also in Northern Ostrobothnia. The aims of the project were to establish new spin-off businesses with the CEMIS members, to network start-ups with existing enterprises and provide more international business opportunities for up-and-coming technology companies, and to identify at least 10 technology solutions with commercialisation potential from the CEMIS members and collaboration networks with a view to commercialising at least four technologies for use by enterprises. A further aim was to provide an exhibition booth once in a year at international trade fairs, produce written and electronic marketing materials, and participate in international technology business events twice a year.

The project was implemented by KAMK and the CEMIS Business Development Unit (CBD), and supported all of the CEMIS members through parallel CEMIS development projects (BIOMIT, KAIMIT and LIIKUTPA).

The total project budget of EUR 550,860 was mainly ERDF funding channelled through the Northern Ostrobothnia Centre for Economic Development, Transport and the Environment (ELY Centre). The project involved separate investment financing for granulation equipment acquired for the KAMK laboratory.

Project results

The KANTELI project developed regional research, expertise and innovation work through CEMIS technology development and the specialist expertise of KAMK. A broader technology business specialist group was established at KAMK as a direct result of the project, and will continue normal operations after the project ends. The project carried out 24 international technology business or technology market surveys for technology and business ideas at various levels of maturity from CEMIS and other regional partners. The target of ten studies envisaged in the project plan was substantially exceeded. In accordance with the project plan, the studies investigated issues affecting the potential of a particular solution or idea for commercialisation and further development, such as business potential and market, existing solutions and competition, technological freedom of action and patentability, and opportunities for financing further development. These investigations identified ten

technologies with spin-off potential that are now subject to further development by various CEMIS partners. Funding for this work has been sought and secured from national and international sources. A patent application has been filed for one technology in the name of KAMK.

CBD technology business surveys have enabled KAMK to reinforce its R&D work, especially in the field of VR/AR solutions. CBD has identified VR/AR technology as a strong new business enabler, and as a developer of existing business operations and processes. KAMK has accordingly established a Virtual Industrial Solutions (VIS) team to support the technical development of VR/AR solutions. Such solutions would include a system for remotely controlling and operating mines, with a view to remotely monitoring the condition of a mine, managing the measures taken and optimising operations. Opportunities have also been identified in other industries, and will be further developed after the project ends.

Technology surveys conducted for MITY and the JYU Vuokatti unit have supported further planning of R&D work in these units, together with commercialisation measures to support such aspects as service sales planning.

Another project segment realised an aim of the project plan with two technology demonstrations in which heavy metals and chemicals were extracted from water by reusing sidestreams from mining operations in the region. The demonstrations strengthened conditions for innovation work at KAMK, and included the following tests:

1. Removal systems for volatile organic compounds (VOC) and ammonia
2. Continuous fixed bed tests on fly ash
3. Replicability of fibre sludge geopolymer tests
4. Phosphate removal experiments on fly ash and blast furnace slag-based geopolymers

Most of the tests demonstrated the effectiveness of the materials and also yielded environmentally acceptable extraction values, providing extensive opportunities for further research and viable use in various environments. Research work will continue in 2019 based on these technology demonstrations.

Internationalisation and networking work, such as participating in technology business events and networking in target countries, continued throughout the project in accordance with the project plan. This work supported the objectives of the project plan and the CEMIS Development Programme, such as strengthening the international R&D and networking of CEMIS in selected target areas including China, South America, Europe and the Middle East. Active contact with specialists and partners and meetings in the field are necessary for launching and realising international development measures, and the visits made in the context of the KANTELI project have led to preparations for numerous development measures. Seeing and experimenting in person with the solutions of potential competitors at various events has provided information that would not otherwise have been available, and the visits have likewise provided some ideas

with the potential to resolve the challenges of developing CEMIS technologies.

Project activities also included attending international trade fairs, international marketing and networking of expertise, and preparation of CEMIS marketing materials as planned. CEMIS and CBD exhibited four times at international technology business events and also participated in four events as a guest.

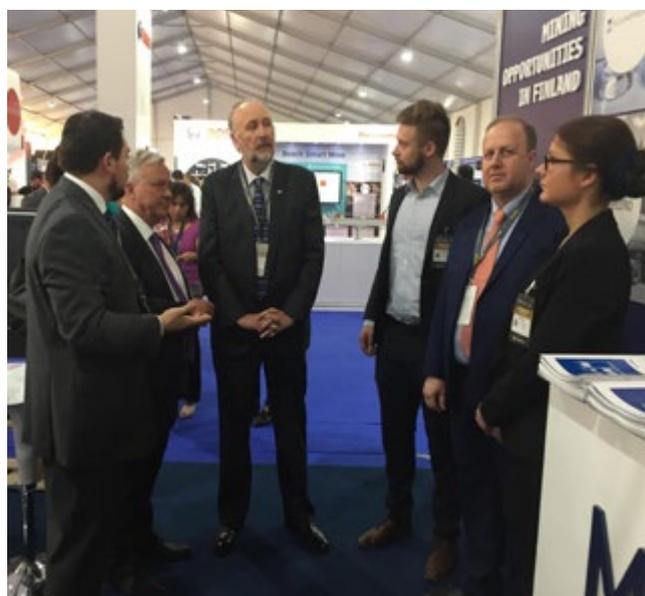


Figure 4.8. CEMIS Business Development unit Manager Dr Anas Al Natsheh (pictured second from right) at the joint booth of Mining Finland for the mining industry EXPOMIN 2018 fair in Chile. Visiting the exhibition booth is Chilean Minister of Mines Baldo Prokurica (pictured centre). Also attending from CEMIS was KAMK Project Manager Esther Takaluoma (pictured right).

Operations of the University of Oulu, Measurement Technology Research Unit

The Measurement Technology Research Unit, MITY, of the University of Oulu continued its work in 2018 through the efforts of two research groups: Cleantech and Health and wellbeing. The unit is based in Kajaani, but also conducts project activities in Vuokatti.

The main application areas of the unit's research in 2018 were bioeconomy (renewable forest industry, bioenergy, use of forest biomass), cleantech (process and environmental applications, especially in mining) and health and wellbeing applications (development of biosensors, nutrition, and development of the Vuokatti area).

A temporary university research fellowship in imaging measurements continued in 2018, and was jointly financed by optoelectronics laboratory projects at the University of Oulu and project funding from the Kajaani Unit. Both research teams included postgraduate degree students.

The volume of unit operations was approximately EUR 3.3 million. A staff of 43 employees completed some 35 person-years of work over the year. The eleven staff members holding a doctoral degree performed 25 per cent of this total workload.

International Project Work

A Slovenian doctoral student financed under the European FP7-ITN network project completed a doctorate at the Unit in March 2018 (Figure 5.2). This EUROMBR project involved 12 partners from 8 countries, developing expertise in microbioreactors. Even though the EUROMBR project ended in autumn 2017, the network has continued operating under finance secured from other sources, arranging a summer school in Germany in September 2018 with a project manager from MITY serving as a lecturer.

A study of co-channel interference caused by electromagnetic scattering by raindrops at the THz frequencies used by future 5G/6G applications, was completed in partnership with the Center for Wireless Communications (CWC) of the University of Oulu as part of the Terranova EU project. The findings of this work were presented



Figure 5.1. The operating and laboratory facilities of MITY are in Kajaani University Consortium at Kajaani Technology Park, Petäisenniska. The MITY laboratory facilities also provide a wide range of chemical analysis and bioanalytical services for business.



Figure 5.2. Peter Panjan (M.Sc. Mechanical Engineering, B.Sc. Biotechnology) defended his doctoral dissertation in Kajaani on 22 March 2018. The picture shows Professor David C. Cullen of Cranfield University, UK, serving as Opponent, with Professor Vesa Virtanen of MITY as Custos and Peter Panjan as Respondent.

at an international flagship conference on communications (IEEE ICC 2019).

The EIP-AGRI SMART FEED project financed by the Finnish Agency for Rural Affairs is collaborating with two Estonian EIP projects (EIP, European Innovation Partnership). The Estonian projects are co-ordinated by the Estonian Dairy Cluster and the Estonian University of Life Sciences. This collaboration has attracted interest at European level, with a news article published in the magazine Agrinnovation in October 2018.

CEMIS Co-operation

The work of CEMIS continued in 2018 with CEMIS Development Programme projects (BIOMIT, KAIMIT and LIIKUTPA):

- BIOMIT - New processes and novel measurements for the bioeconomy and for the mining industry: This project sought to reduce industrial carbon dioxide emissions by developing measurement solutions to optimise bioenergy generating and mining industry processes. It also sought to reduce the environmental impacts of industry by developing solutions for water management in the process and mining industries, and new methods for efficiently using biomass and sidestreams in Kainuu according to the principles of a circular economy. The project ended at the end of the year, and it enhanced expertise in studying the research benefits of computer-assisted modelling and developed two new measurement technologies. Two new start-ups applying the results of the project are at the planning stage.
- KAIMIT - Novel environmental measurements for mining and other industry discharge waters: This project focuses on developing new measuring methods for monitoring industrial discharge waters, with particular reference to sulfate and phosphate assays lacking reliable and cost-effective commercial field measurement solutions. MITY is applying its cutting-edge

expertise in electrochemistry and optics/photonics to this research challenge. Methodological progress will also apply the principle of multimeasurement, combining signals from several modes of measurement. MITY and VTT have continued applying computer simulation for understanding processes and phenomena in research and hardware development, with simulations performed especially for fluid flows and electrochemistry. The project will continue until the end of 2019.

- LIIKUTPA - New sport and wellbeing technologies and services. This project was co-ordinated by the University of Jyväskylä. It developed measurement methods for health and wellbeing applications, especially to boost development of the Vuokatti sports and tourism environment. Methods were developed for measuring nutrition and stress markers in saliva. New initiatives were also sought to meet the needs of businesses. The project was completed at the end of the year, resulting in the creation of a test prototype of a new miniaturised mobile biosensor meter and three new commercialised configurations for service analytics.

The CEMIS Development Programme has again combined expertise in the field with collaboration between Jyväskylä and MITY, and between MITY and VTT. Research co-operation with the University of Jyväskylä and VTT was also reinforced through Business Finland projects. Director Vesa Virtanen participated in the work of the CEMIS Strategy and Management Groups. The University of Oulu unit is clearly the largest single research operator in the CEMIS Development Programme.

Other Project Activities

MITY had 5 ongoing projects funded by Business Finland (formerly Tekes).

1. The ICEMET project (Business Finland, New information and business from research ideas, TUTLI funding) is preparing commercialisation of a system for forecasting the icing condition of wind turbine blades.
2. DentSaver (oral health screening and treatment guidance service for health kiosks) project (Business Finland, TUTLI funding): Oral health assessment tools for use elsewhere than dental surgeries.
3. The CRYSTAL project (Challenge Finland funding from Business Finland) seeks to improve the ophthalmic healthcare chain by providing new computer-aided solutions for detecting symptoms of ocular disease.
4. The Virtual Coach Project (Business Finland, ERDF funding) involved four CEMIS partners co-ordinated by the University of Jyväskylä. MITY developed a new, smaller and more versatile version of a biosensor reader.
5. The EXTREAM project (Extraction of valuable compounds from bioeconomy industry side streams) relates to an already existing industrial ecosystem. This project applies environmentally friendly extraction technology (supercritical carbon dioxide extraction) to sidestreams from the mechanical forest industry and forestry residues to produce fat-soluble biochemicals, and

develops a real-time method for measuring the size of wood chips. The extraction technology will be piloted on a scale that can be scaled up to production plant size. Small-scale extractions will be performed under laboratory conditions, with larger-scale pilot projects taking place in an Austrian plant that manufactures hardware on an industrial scale. Real-time measuring of chip size will be piloted in a factory environment. The project will develop cost-effective, continuously operating and reliable measurement of chip size based on camera technology and optical measurement for a falling sample, as applied to various sidestream products (such as woodchips). The first large-scale pilot initiative was carried out in Austria with promising results. The project will continue until the end of 2019, with ERDF funding via Business Finland.

Besides its CEMIS Development Programme and Business Finland projects, MITY had 11 other ongoing initiatives, pursuing industrial collaboration with dozens of enterprises in the Kainuu region and nationally.

The unit is involved in a project funded by the Academy of Finland entitled "Single-photon detector array for simultaneous label-free Raman and fluorescence lifetime spectroscopy". This involves developing combined Raman/fluorescence lifetime hardware.

The Analytical Services and Profitability of Biogas Production in the Kainuu Region (BITES 1 and BITES 2) project was implemented in partnership with specialists from Measurepolis Development Ltd., which merged with KAMK in 2017. The aim was to boost farm-scale biogas production in Kainuu with a broader raw material base, process competence and optimisation, support the development of biogas business models in Kainuu, promote growth in the biogas production services business focusing on the analysis of various types of biogas reactors, and formulate and acquire new information on biogas process operation and optimisation. The projects developed analytics for monitoring the operation of biogas processes, which were successfully field-tested at a biogas plant in 2018. The project outcomes were presented in autumn 2018 at the 12th World Congress on Biofuels and Bioenergy in Zurich, Switzerland. The project ended in 2018.

The Management and Restoration of Lakes Receiving Mine Waters (KaiHali) project developed expertise and business related to ways of managing watercourses that receive mining effluent and to remediation of such waters. Concrete measures have included modelling the propagation of discharges, developing stratification and BLM models, developing autonomous vessel profile measurements, and practical remediation trials. The project was implemented by the Finnish Environment Institute (co-ordinator), the Geological Survey of Finland, KAMK and MITY. It ended at the end of 2018.

The Drones in Measurement and Sampling (DROMINÄ) research project studied the prospects for using unmanned aerial vehicles (drones) in water quality measurement and sampling. This project explored novel measurement and sampling strategies suitable for drones, and demonstrated their operation in measuring and sampling

water quality in waterways and process water basins. It led to the development of a drone-compatible water sampler and two types of measurement and sampling package. The project was completed in partnership with the Finnish Environment Institute (SYKE) and the Geological Survey of Finland (GTK). It ended at the end of 2018 and was financed by the Centre for Economic Development, Transport and the for Northern Ostrobothnia (ERDF funding), Sotkamo Silver Oy, Infrasuunnittelu Oy, WND Solutions Oy, Savo-Karjalan Ympäristötutkimus Oy and the implementing organisations.

Funded by the Finnish Agency for Rural Affairs, the project „Improving the Quality and Safety of Natural Products” (PALKO 1) developed methods of ensuring the quality and safety of natural products, especially in the natural cosmetics industry. The PALKO 1 project focused on natural plant extraction trials and analysis, and on improving methods of investigating the shelf lives of natural products. The Finnish Agency for Rural Affairs funded the parallel PALKO 2 and PALKO 3 projects in 2017. PALKO 2 supplemented the extraction trials, using them to formulate training packages, and also developed analytics for studying the activity of cosmetics based on cell culture testing. PALKO 3 is using various enterprise samples to optimise and finalise the development of analytics. Ten natural product industry businesses are involved in the project. PALKO 2 and 3 will be completed at the end of 2019.



Figure 5.3. The bioeconomy is one of the main research fields at MITY. Besides more traditional fields of the bioeconomy, such as the forest industry and bioenergy, MITY is studying the use and processing of valuable components in berries, e.g. for use in the health products and cosmetics industries.

The KryoMikro project studies the applicability of two untapped technologies – cryoconcentration and microwave processing – in the Finnish process industry for processing food and natural products, and for treating fractions recovered from the wastewater streams. This project has made Finnish operators aware of technologies that are gaining ground globally, with a view to improving the viability, productivity and competitiveness of their operations. The KryoMikro project will end in April 2020.

The Use of Smart Specialisation to Improve Industrial Competitiveness project enabled MITY and businesses to support the development of electrochemical technology and the use of new international

financial instruments to promote smart specialisation in Kainuu enterprises. It also reinforced the smart specialisation ecosystem. A testing environment designed during the project will be of particular value to microbusinesses and SMEs in the region. Project initiatives included preparing enterprise-driven international projects for EU programmes, and promoting SME growth, export operations and globalisation. The project ended in 2018. Participants included Valmet Automation Oy, Meoline Oy, Kainuun Etu Oy, Oy Culmentor Ltd and Solved - The Cleantech Company Ltd.

Financed by the Finnish Agency for Rural Affairs, the national "smart measurements in cattle feeding and healthcare" project (ÄLYREHU) is one of eight Finnish EIP projects in agriculture (European Innovation Partnership). It works with farmers and specialists to improve on-farm measurements and data communication applications that monitor fodder quality and the welfare of livestock.

Co-funded by the European Maritime and Fisheries Fund (EMFF) and co-ordinated by Natural Resources Institute Finland (Luke), a large-scale project entitled Successful fish releases assigns MITY to discharge a proof-of-concept (PoC) segment with a view to developing field-capable measurement of cortisol stress hormone suitable for use in fish farm basins.

MITY has also been involved in a proof-of-concept (PoC) project funded by the Innovation Unit of the University of Oulu, which focused on the use of tissue modelling in teaching neural networks.

Research Collaboration and Publications

Fruitful co-operation continued with the Joensuu campus of the University of Eastern Finland. One theme of this work has been the use of optical methods to detect adulteration of liquid fuels. A study was also launched to detect microplastics in watercourses. The aim is to develop a measuring device for attachment to vessels that will detect the presence of microplastic particles in real time.

MITY is involved (between 2018 and 2020) as an academic mentor in Bioeconomy specialisation training, a joint educational project of the University of Eastern Finland (Kuopio and Joensuu campuses) and the Savonia and Karelia universities of applied sciences. In addition to mentoring, the MITY laboratories and their equipment have been available for academic thesis work.

Collaboration with the EUROMBR network produced a total of three scientific articles in 2018.

International researcher exchanges amounted to some 31 person months. Active international co-operation involved more than ten research institutions from countries including Italy, Denmark and the United Kingdom. A healthy number of academic articles were produced, with 12 refereed international scientific articles and 4 conference publications. Unit staff participated in national and international evaluation assignments (peer reviews for academic journals, opposing doctoral dissertation defences, and assessing

international project applications). Three invention notices were filed.

Operations of Kajaani University of Applied Sciences

Productivity indicators compiled by the Finnish Ministry of Education and Culture suggest that Kajaani University of Applied Sciences (KAMK) was Finland's most successful institution of its kind in 2018. These findings were also reflected in several key figures for research and development. A record 78 development projects were ongoing over the year, including 11 international projects. External RDI funding grew by 14.5 per cent.

Statutory amendments enabled a fundraising campaign in 2018 that raised a total of EUR 354,183,78 in donations for KAMK. Investment in commercial operations continued, and were reflected in a good level of business turnover. The first educational export deals were also implemented.

KAMK operations at CEMIS involved 3 areas of expertise in 2018: Information Systems, Mechanical and Mining Engineering, and CEMIS Business Development (CBD). CEMIS operations were also effectively linked to KAMK research, development and innovation operations (RDI) in the joint preparation of project applications. The reassignment of Rector Turo Kilpeläinen brought a change of leadership at KAMK in the spring and the university has been headed by Dr Matti Sarén since March 2018.

The School of Information Systems as a Strong Operator in Regional Development

Successful regional development in Kainuu requires foresight, an appreciation of global trends, and the ability to respond to changes in operating conditions. The School of Information Systems has placed special emphasis on interacting with the world of work, successfully collaborating with businesses to meet the need for training in our region by offering programmes in such fields as Vehicle Information Systems, Data Centres, Intelligent Systems and the games industry. Actively collaborating with the world of work enables us to reform as conditions change globally. 2018 was no exception to this general trend. Collaborating with the world of work remains very important to us, and we have continued to open up new pathways. 2018 proved an important year for our evolving operations. The outlook for business growth and wellbeing in Kainuu now seems more favourable than it has been in a long time, with several success stories in our region falling within our fields of expertise.

The key figures for 2018 in those fields were 69 completed first degrees and one postgraduate degree in data processing. 16 publications were released, with our 36 staff members divided roughly equally between teaching and RDI functions.

An important year for business development in 2018

The Information Systems unit launched several significant and far-reaching new initiatives in 2018, of which the most notable were:

- Donation from CSC – IT Center for Science Ltd. of a BULL supercomputer, which was commissioned in November 2018 (Figure 6.1).
- Work was launched to design a new type of IT engineer training programme with a view to meeting the needs of regional development and making engineer training a more attractive option. The rapid course design work cycle aims to offer a programme From Data to Artificial Intelligence for general application in spring 2019, with studies commencing in the following autumn.
- Work of the national Allied ICT Finland (AIF) network
- Game industry summer school in India
- Designing an international student course programme
- Developing training for entrepreneurship

Computing cluster introduction is a first for a university of applied sciences in Finland

Effective application of artificial intelligence (AI) requires a wide range of multilevel expertise and appropriate infrastructure to store and process a growing volume of data. The key status of data in digitisation and AI applications has been compared to that of oil in an economy.



Figure 6.1. Official commissioning of the BULL supercomputer at KAMK on 11 December 2018. Attending the commissioning ceremony (pictured left to right) were Kimmo Koski, Managing Director of CSC – IT Center for Science, which donated the supercomputer, KAMK Rector Matti Sarén, and Kimmo Nikkanen, Head of School, Information Systems, KAMK.

Credit: Photo by Petri Hakkarainen, Kaleva Media

Data volumes are increasing all the time, and methods for processing data are evolving rapidly.

To meet data-driven RDI and training needs, a BULL hybrid system acquired from CSC – IT Center for Science was assigned to KAMK in spring 2018 (Figure 6.2). The commissioned supercomputer complements a student-maintained data centre environment that is unique by European standards. With an energy-conserving liquid cooling system, the supercomputer has the processing power of 75 gaming PCs and generates enough heat comparable to 8 Finnish sauna stove (6 kW each) when operating with full capacity. Besides this supercomputer, KAMK acquired a separate multi-use computing cluster of graphics processors in autumn 2018, suitable for such applications as game graphics computing and data mining. The investment was part of the TOLKKU project, and was subsidised by an ERDF grant channelled through the Regional Council of Kainuu. Besides the data centre infrastructure at KAMK, this project includes modernising the hardware and software base of the electromagnetic compatibility laboratory (EMC) that provides testing services for electronics, and the VR First laboratory that specialises in developing serious games. The project has taken the quality and impact of these learning, RDI and service environments to a new level.

Designing a New Education Programme - From Data to Artificial Intelligence

Effectively applying artificial intelligence requires a wide range of multilevel expertise and appropriate infrastructure to store and process a growing volume of data. Estimates suggest that there is a serious shortage of digital services production expertise in Finland, with about 15,000 more software developers and professionals required in the next few years. This figure also includes the specialists in cloud services, computing platforms and data analytics required at various stages of implementing AI applications. This shortage of specialists is a significant barrier to national success in the software



Figure 6.2. The BULL supercomputer complements a student-maintained data centre environment that is unique by European standards.

sector and in other fields of a rapidly digitising society.

To meet the evolving needs of the software industry for expertise, we prepared and successfully secured financial support for the DAIIKA project (ESF funding, 2019-2021) to design, develop and pilot a new From Data to Artificial Intelligence (see <https://iamai.fi/en/>) engineer training programme that is scheduled to begin in autumn 2019. This practical programme will specifically focus on the core skills of the artificial intelligence solutions value chain: data management, pre-processing and editing, computing infrastructure and data analysis. Strategic development funding granted by the Ministry of Education and Culture will also be allocated to developing the programme. The new training will be linked to existing training in the KAMK School of Information Systems, i.e. Data centre, Games industry, and Intelligent systems.

The combination of supercomputer, GPU computing cluster and data centre learning environment is highly significant to KAMK, as it strengthens and expands the skills base in a field of national and international importance. The hardware is also of great value to data centre industry students, who will be able to use the new combination for practical exercises with businesses and partners, thereby gaining an edge in the job market. As a local operator in Kajaani, CSC – IT Center for Science is an important partner to KAMK.

Full use of the computing cluster also involves designing a new type of IT engineer training, with the groundwork and decision to launch the training programme From Data to Artificial Intelligence completed in 2018. The programme focuses on applying a strong national position in training basic data engineers to boost regional development, and training IT engineers equipped with new ICT skills to meet the needs

of Finland as a whole.

Substantial project funding to commission the computing cluster, build the service portfolio and develop the training programme was received from Kainuu Centre for Economic Development, Transport and the Environment, and from the Regional Council of Kainuu, together with direct financing from the Ministry of Employment and the Economy.

The national Allied ICT Finland (AIF) network

The substantial investment by the School of Information Systems in the computing cluster and new training programme was also reflected in a broadening of horizons and opening up of new partnership networks, as KAMK was invited to join the national Allied ICT Finland (AIF) network (<https://alliedict.fi>). AIF will provide new opportunities not only for training and infrastructure development, but also for project collaboration.

Game development summer school in India

Game development is one of the most popular programmes in the School of Information Systems at KAMK. This is probably because our study programmes comply with game industry standards, working with the international game industry community, our students have excelled in various national and international competitions, and our graduates have found significant positions in leading game industry enterprises.

Our game development programmes have also attracted considerable interest outside Finland. At the invitation of the regional Ministry of Education in Andhra Pradesh, we arranged a summer 2018 games industry school in Vijayawada, India. The summer school was held at SRM University in India and was attended by 500 Indian students from dozens of universities. The summer school was rated as a 10-credit, 6-week intensive course. Teaching was arranged on site with 8 lecturers from the School of Information Systems. Students created dozens of playable games during the summer school, with several game teams managing to publish their games on Google. A total of 6,000 ECTS credits were awarded, generating nearly EUR 1.6 million in cash flow for the KAMK as Open Studies of University of Applied Sciences. The direct costs of the summer school totalled approximately EUR 110,000. The summer school was a success story that attracted huge publicity in India.

Designing an international student course programme

In the wake of the successful summer games industry school in India, substantial planning took place towards the end of 2018 for further events of this kind in India and other countries. The primary interest in the international market is to attract students to Kajaani and the Kainuu region. This aim requires us to find enough international students who have completed the 60 credits needed for direct admission to a degree program by individual application. Planning of new international initiatives must also allow for obstacles such

as the negative attitude of the Finnish Immigration Service towards accelerated processing of foreign student visa applications.

Developing training for self-employment

There has been no increase in the number of businesses in Kainuu in recent years, which is a worrying signal. A thriving and growing business sector is the foundation for developing the region. Alongside existing strong enterprises, new businesses are needed to open up markets in new sectors. As the region's most important provider of skills, KAMK plays a key role in generating new entrepreneurship. We have established structures to support student entrepreneurship over the years, including:

- Incorporating business studies and entrepreneurship training in all course programmes.
- Operating a Young Entrepreneurship study programme, with 30-40 students enrolling each year to earn 10 ECTS credits related to self-employment. Practical business operations under the KAMK Business ID are an essential part of these studies, with turnover not exceeding EUR 10,000.
- KAMK teams have been highly successful in national competitions (Yes and NyStart Up).
- The KAMK Innovation Jury grants funding of between 100 and 3,000 euros to students for ideas with commercial potential.
- KAMK has two co-operatives (Kajak Games and Kajability), incorporating a few dozen students and six enterprises. These co-operatives give students a risk-free opportunity to start a business using an auxiliary trade name.
- KAMK has made progress in supporting entrepreneurship through previous projects such as Innova (2010-2012) and the ongoing YES entrepreneurship education projects.
- Trials have also been conducted in the games industry at KAMK using student teams and enterprises, but these operations are not yet well established or systematic.

These arrangements have largely been established over the last three years, without significantly increasing the number of graduates going into business. Some 10 to 15 graduates continue in business after completing their programmes at KAMK, representing 3-5 per cent of each graduating class. The number of businesses established is much smaller than this, as graduates launch joint enterprises, especially in the games industry. Many student businesses remain immature, with only a limited ability to survive the critical early years.

Business development services intended to support innovative business ideas and enterprises with growth potential currently consist largely of standalone services provided by various projects and operators. These services seem fragmented and hard to conceptualise from the perspective of clients. Anyone developing a new business idea, product or service has difficulty in identifying the operators and their roles. Instead of individual services, new graduates or student

entrepreneurs need single-window access to the services of various specialists. This was the motivation for building and launching the new Accelerator project in the School of Information Systems, which got off to a strong start with the earliest results already achieved in 2018 in the form of new start-ups.

Project operations

Projects are a major driver of our operational development and partnership with enterprises. The School of Information Systems continued its solid work of previous years by securing many favourable project funding decisions. Perhaps the most significant favourable decision came in the form of approval of our first ever directly EU-funded Horizon 2020 research project. This Faster project (First responder Advanced technologies for Safe and efficient Emergency Response, <https://www.faster-project.eu>) is developing mobile and virtual solutions to enable rescue agencies to work more effectively in partnership with the City of Kajaani and nearly 30 international partners.

The world of work seems to be involved in all our projects, which continue to focus increasingly on providing optimal teaching content and avoiding isolation. This work has yielded excellent progress and success. The total volume of project operations in the School of Information Systems was a significant EUR 1.2 million in 2018, with service sales in this competence area generating some EUR 180,000 in value. We would like to thank our corporate financing partners and principal project financiers: the European Union, the Centre for Economic Development, Transport and the Environment, the Regional Council of Kainuu, the Ministry of Education and Culture, and the

Ministry of Employment and the Economy.

Mechanical and Mining Technology as a Secure Employment Provider and Strong Project Participant in the Region

Based on enterprise contacts, the mechanical and mining engineering competence area at KAMK has identified a particular need in the industry of the region for employees with a grounding in engineering. We have developed various forms of co-operation that bring enterprises into even closer contact with our students during their studies. In recognition of this, we were able to negotiate two-year funding including a one-year option for a senior lecturer position in process industry with the mining company Terrafame Oy. We are thereby seeking to promote all forms of co-operation between Terrafame Oy and KAMK, and to ensure that this company secures skilled employees as it grows into a major operator in the European battery chemicals industry.

Our key figures for 2018 were 43 first and 7 postgraduate degrees completed. We issued 13 publications and secured approximately EUR 850,000 in external RDI funding for the competence area. An average of 30 staff members were divided roughly equally between teaching and RDI operations.

Several projects were ongoing, subsidised by numerous Finnish and

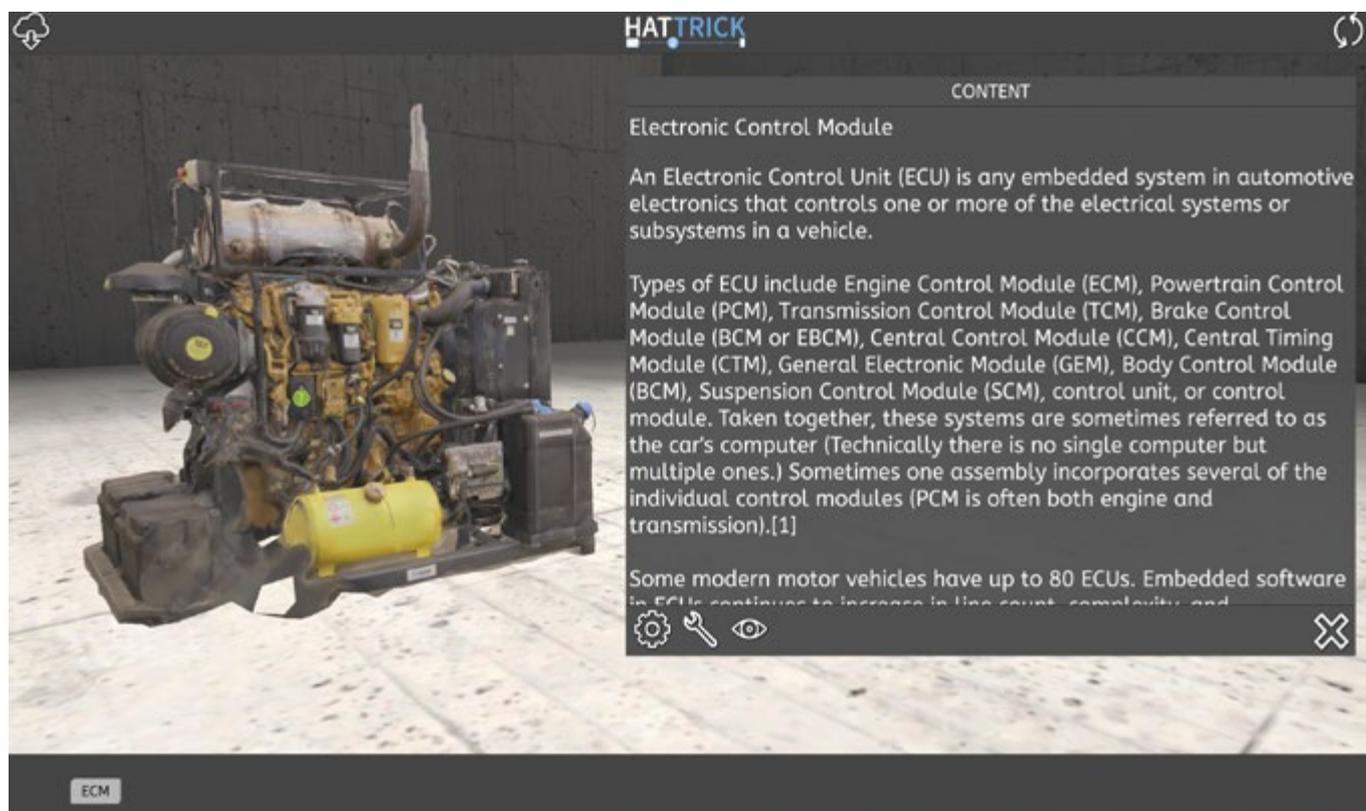


Figure 6.3. The HatTrick project packaging Kainuu educational expertise into an export product has developed an editor tool that readily enables educators to produce educational materials around a 3D model.

international financing instruments. The aim is to continue actively globalising our R&D work, strengthening our own field of expertise as a provider of water treatment solutions and materials. This field of competence has identified some 5 applications in which it intends to be actively involved over the final few years of the Horizon 2020 programme.

The volume of service business in the competence area increased slightly from the level of the previous year to total approximately EUR 100,000. Virtual reality solutions are of particular interest to industry (Figure 6.3), and expertise has been advanced throughout KAMK by more than 20 specialists divided into two teams with both project and service business funding.

Training and project co-operation continued in the Raahelä region, resulting in a commitment by SSAB Europe Ltd., one of Europe's largest steel industry operators, to the new CEMIS development program that will begin in 2019.

Planning and development of expertise and skills for the mining industry continued with Lapland University of Applied Sciences and Oulu Mining School, with a view to launching an international mining industry summer school in 2019.



Figure 6.4. An engineering student group from KAMK was placed second in the SICK Innovation Contest with its application „Fill Monitoring of an Unmanned Warehouse or Hall“. Receiving the prize in Helsinki on 4 April 2018 are Juha Junttila, Olli-Pekka Hakala, Innovation Project Manager Niina Halonen, Tuukka Rossi and Petteri Weck.

Particularly noteworthy in 2018 was the great success of KAMK mechanical engineering students in the SICK Innovation Contest, where our first-year students secured second place (Figure 6.4). The aim of the competition was to brainstorm, invent, construct and document a new idea in a freely chosen field using SICK products. SICK is one of the world's leading manufacturers of sensors and sensor applications for industrial, logistics and process automation applications. It has been arranging its innovation competition for several years. This was the first time that a prize had been awarded to students at KAMK. The overall best entry was a 3D rollator designed by Vaasa University of Applied Sciences, with Metropolia, Novia and Aalto universities taking third place. The prizes were

awarded at the SICK Innovation Event in Helsinki on 4 April 2018 by Olli-Pekka Heinonen, Director General of the Finnish National Agency for Education.

International Technology Business Development - CEMIS Business Development (CBD) in 2018

Operating since CEMIS was established in 2010, the CEMIS Business Development (CBD) unit continued in 2018 under the direction of Leading Business Development Specialist Dr Anas Al Natsheh. The number of business developers working in the unit increased to four, with the unit also employing several students as interns. Collaboration with a broader team of KAMK specialists was fruitful in operating and preparing projects, and close collaboration with other CEMIS partners similarly continued, with significant future business potential identified in several CEMIS technologies.

CBD worked intensively on the International Technology Business project (KANTELI) in 2018. This work supported the technology development efforts of the CEMIS partners through various studies of business opportunities and globalisation measures. The KANTELI project produced extensive studies for partners in key fields for CEMIS and the Kainuu region, such as Virtual Reality (VR) and Augmented Reality (AR) solutions, cleantech, bioeconomy, and health and sports technology. New information was made available particularly on the opportunities of IoT and digitalisation, which is relevant to several CEMIS research fields. Especially important progress was made in the VR/AR solution teams, with a dedicated Virtual Industrial Solutions (VIS) team established under KAMK to develop this work.

VR/AR applications and solutions are being deployed at an accelerating pace in various industries, with KAMK launching its Future Mine project (financed by Business Finland) in this context in autumn 2018. This project seeks to study and develop a comprehensive solution that will apply virtual reality (VR) and augmented reality (AR) for enhancing the design of mining operations and other activities (Figure 6.5). CBD is responsible for the commercial research and VIS technology development of the project, which will continue until 2020.

The international work of CBD was mainly done in the KANTELI project by participating in several international events, such as trade fairs, conferences and various networking events that were mainly held abroad. Participation has been important not only for marketing, but also for creating and reinforcing new networks, exploring business opportunities, and examining market solutions for various technologies. Some principal events included CES 2018 (one of the largest technology business events in the USA), EXPOMINA in Lima, Peru, and the International Water Summit for the cleantech sector in Abu Dhabi, UAE.

In addition to the previous target markets of Europe, South America and the Persian Gulf, CBD has continued working in the Chinese

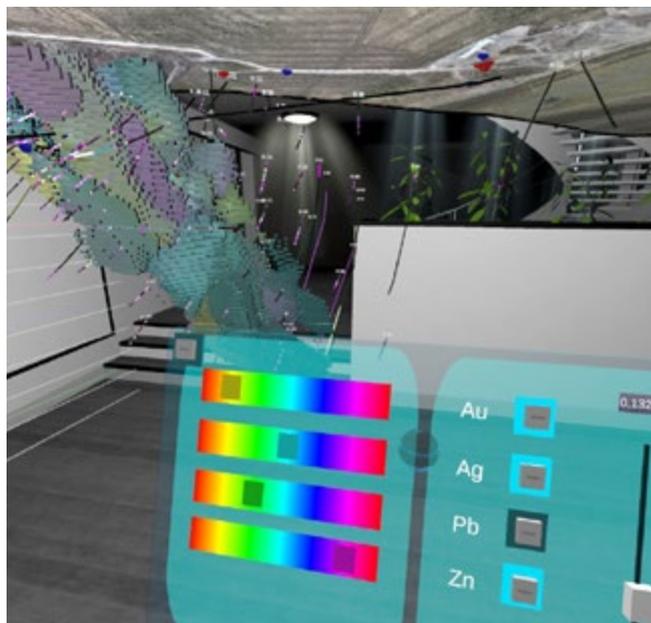


Figure 6.5. The OredVR project is developing a virtual reality solution that brings a new dimension to mine planning and policymaking. The picture shows a mine tunnel and the surrounding ore reserves, from which a geologist or other specialist may filter the view to focus on selected ores exceeding certain concentrations.

market. Unit Director Dr Anas Al Natsheh and CEMIS Director Mikko Kerttula joined a ministerial-level Finnish delegation on a visit to China in March.

The technology demonstrations of the KANTELI project were completed during 2018. Test results on the effectiveness of adsorbent functionality in removing and recovering metals and sulfates were highly promising. Technology demonstration results recorded at KAMK continue to provide a firm foundation for developing geopolymers.

CBD continued active and fruitful collaboration with several KAMK departments, the Measurements Technology Unit (MITY) at the University of Oulu, the Vuokatti Sports Unit of the University of Jyväskylä, VTT - Technical Research Centre of Finland, and CSC - IT Center for Science. Significantly strong collaboration continued with the University of Jyväskylä to develop the service business related to measurements of sporting performance and wellness. An important part of CBD work in the KANTELI-project has been to pursue development of Kainuu-based technologies and seek international opportunities for them. This work has made CEMIS technology developers and researchers more aware of the needs and requirements of customers, provided details of the market, IPR and competitors, and launched efforts to commercialise the most promising technologies. International market research is essential for certain industry-supporting technologies and solutions addressing the needs of specific industries and processes that are practiced only on a limited scale in Finland.

A new BUZTECH project interviewing several newly-established Finnish enterprises operating in CEMIS-related industries will help CBD to gain first-hand information on the emergence and growth of technology businesses for CEMIS partners and fields of operation.

This study will be quite extensive by Finnish standards, and the project (2019-2020) will seek to collate expertise and best practices for potential future start-ups with a view to reducing the typical initial Death Valley stage and avoiding factors that retard business growth.

The KANTELI International Technology Business project was completed at the end of 2018, with CBD serving as its principal project partner.

Operations of VTT Technical Research Centre of Finland in Kajaani

The work of VTT Technical Research Centre in 2018 in Kajaani continued to focus on the Metrology operations of VTT MIKES. This facility is the world's northernmost National Standards Laboratory, and has been operating since 2011 in purpose-built premises at Renforsin Ranta Business Park.

VTT MIKES is a research area within the VTT organisation that serves as the National Metrology Institute of Finland (NMI). It is responsible for implementing SI measurement units in Finland and for developing, maintaining and co-ordinating the national system of measurement standards.

The work of VTT MIKES in Kajaani has focused on traceability services for measuring force, mass, torque and fluid flows, developing metrology, and industry research. The national measurement standards for force, torque, fluid flow and large masses exceeding 20 kg are based in Kajaani. These standards are applied when calibrating measuring instruments to determine the error between the instrument readout and the standard. VTT MIKES Kajaani is involved in the work of the national VTT metrology stakeholder group, responsible for the force and fluid flow clubs.

2018 was a smooth year for VTT MIKES, with no major staffing changes. A total of eight people worked in two VTT research teams (BA1609 and BA1704) at the Kajaani facility. Operations developed as expected over the year with regard to traceability services and research. The annual clientele has remained steady at about 250 clients per year, with over 95 per cent based outside the Kainuu region. There are more foreign than Kainuu-based clients. The location of the laboratory has proved well suited to its operations and appropriate for its clients over the years.

The UWB (Ultra-Wide Band) impulse radar and positioning technology development work that began in Kajaani a decade ago reached a point at which it is now being continued by the spinoff business Iiwari Tracking Solutions Ltd.

International Collaboration

The VTT MIKES force group has been actively involved in the work of the European Association of National Metrology Institutes (EURAMET), including its technical meetings related to the specific physical quantities for which the unit is responsible. The staff at Kajaani also include the official Finnish representative on the EURAMET

Technical Committee for Flow and on the TC3 (Measurement of Force, Mass and Torque) technical committee of the International Measurement Confederation (IMEKO). VTT MIKES Kajaani took part in two projects (MultiFlowMet II and MetroWaMet) of the European Metrology Programme for Innovation and Research (EMPIR), and one new force measurement project was also prepared.

Research

VTT MIKES Kajaani actively participated in implementing the CEMIS Development Programme joint projects BIOMIT (New processes and novel measurements for the bioeconomy and mining industry) and LIIKUTPA (New sport and wellbeing technologies and services).



Figure 7.1. Martti Heinonen, D.Sc. (Tech.) (right) started as the Vice President of VTT MIKES research area at the beginning of 2018. Dr Petri Koponen works as research team leader in VTT MIKES Kajaani.

LIKUTPA is co-ordinated by the University of Jyväskylä, with VTT providing expertise in measurements and measurement methods for skiing equipment. Suitable sensors for roller skis were designed and made in 2018 enabling attachment of roller skis to VTT MIKES force measurement standards for the purpose of measuring force (Figure 7.2). Use of these measuring standards significantly improves the comparability of ski parameterisation results. A fixed force sensor for roller skis that measures the downward force exerted by a skier was completed in 2018 (Figure 7.3). This will serve as a basis for future more sophisticated sensor solutions.



Figure 7.2 Roller ski test measurements in progress at a 20 kN force standard at VTT MIKES in Kajaani.



Figure 7.3 Petri Koponen, Research Team Leader at VTT MIKES Kajaani, presents roller ski force sensors.

The BIOMIT project enabled VTT MIKES Kajaani to enhance its own expertise in Computational Flow Dynamics (CFD). The goal was to learn how to use open-source tools (including OpenFOAM®) effectively in CFD computing. A further challenge is to study phenomena occurring in a multiphase environment and learn the fundamentals of individual fibre modelling in pulp. A gas or liquid flows conventionally containing fibres has been simulated using the Eulerian-Eulerian two-fluid approach, in which the flow is considered to consist of two liquids, one containing the gas or liquid phase and the other containing the fibres. The project explored the prospects for simulation without gas or fluid flow using a different approach: the fibre-forming phase is not treated as a continuous phase, but the individual fibres are simulated

as separate items. The simulation also allows for the finite stiffness of the fibres. This is demanding and requires a great deal of computing power. The work will continue.

VTT MIKES Kajaani has also been involved in preparing other publicly funded research projects and in customer-oriented research projects. These research questions also related to the standards maintained in the unit, and to their application in various measurements.

Outlook for 2019-2020

The prospects for 2019 are promising. New research projects are under way in which metrology and its application play an important role. Collaboration with various stakeholders has continued to grow, and co-operation within VTT has also increased significantly, which also brings benefits for CEMIS.

The importance of measurement reliability has continued to grow in the business world, with enterprises increasingly appreciating that reliable measurements provide quality, market value and a competitive edge in their operations. The share of traceability services in the unit's budget is expected to remain strong in 2019, and the unit's high metrological standard will be maintained by participating in international research and benchmarking projects.

Operations of the University of Jyväskylä in Vuokatti”

A partnership of the University of Jyväskylä, Vuokatti Sports Institute, the Municipality of Sotkamo and CEMIS envisions the transformation of Vuokatti into a world-renowned and unique centre for research, training and testing of winter sports, and especially cross-country skiing. Vuokatti provides a wide range of research environments for Nordic ski sports, and has continually expanded and developed over the years.

Vuokatti sports technology unit is part of the Faculty of Sport Science at the University of Jyväskylä. The unit's laboratory facilities at Snowpolis Technology Park provide the latest technology for physiological and biomechanical measurements. A testing and research environment for both ski jumpers and ski tunnels has also been developed together with Vuokatti Sports Institute. The aim of the Master's and doctoral degree programmes is to nurture future talent, particularly for businesses operating in the growing wellness and sports technology sector, and for research of an international standard. The Vuokatti unit of the University of Jyväskylä has also significantly supported the growing co-operation of Vuokatti Sports Institute in coaching Chinese winter sports athletes in recent years.

General Overview

Vuokatti sports technology unit provides master's and doctoral degree programmes in sports sciences and pursues research and development projects with national and international partners. In addition to its educational functions, the unit specialises in R&D projects with a view to facilitating both individual exercise and wellness measurements and advanced measurement technologies for use in industry. A total of 13 people worked at the Vuokatti unit in 2018, including a full-time staff of seven employees. Three staff members are co-employed by the University of Jyväskylä and the Finnish Ski Association, the Finnish Biathlon Association or the Finnish Olympic Committee, and one staff member is partly self-employed. The Vuokatti unit is headed by professor Vesa Linnamo. The unit is based at premises in Snowpolis Technology Park in Vuokatti, Kainuu. Over the year the staff at Vuokatti published five original scientific papers, three books or book chapters, and two international congress abstracts, and gave a total of six invited presentations, of which four were delivered in an international context. The sports technology unit has arranged a total of six international congresses or seminars at Vuokatti over the years, including the Post Olympic Winter Games Seminar in 2018 (Figure 8.1), which attracted some 130 participants

from eight countries. The seminar was arranged in partnership with the Scandinavian Network for Elite Sport. Preparations began in mid-2018 for the „8th International Congress on Science and Skiing” to be held in March 2019.



Figure 8.1. Finnish women's national ice hockey coach Pasi Mustonen, whose team won the bronze medal at the PyeongChang Olympics, addressing the Post OWG seminar.

Partnerships

R&D projects implemented with national and international partners form a significant part of the unit's operations. The unit has engaged in R&D work in measurement of individual sporting performance or wellbeing, and in advanced measurement technologies, both alone and substantially in partnership with CEMIS organisations. CEMIS operations in particular have provided a rapid response capability ensuring continued competitiveness in technological development in the swiftly advancing fields of sports and wellness technology. The unit's R&D work is increasingly based nowadays on the needs

of the sports sector, with the indirect impact of its findings visible in the form of growth in Vuokatti sports tourism and development of the associated brand. The unit has been successfully involved in the progress made by Finnish skiers, for example through the work of Olli Ohtonen, who is completing his doctorate in skiing biomechanics at Vuokatti and served as personal trainer to Olympic 50 kilometre gold medallist Iivo Niskanen. Work with CEMIS partners also led to the development of testing methods for Nordic skiing equipment, such as ski and pole testers, and related research findings have been systematically shared with the service crews of Finnish national teams.

Research collaboration with the International Paralympic Committee concerning the sit skiing classification process has continued in partnership with universities in Turin, Gothenburg and Leuven. A research team conducted interim analysis measurements at the PyeongChang Paralympic Games in March 2018, and international collaboration also continued with Beijing Sport University, from which a delegation of eight persons visited the Faculty of Sport Science for six months in order to study issues related to winter sport. This visit included spending two months at Vuokatti in the early winter of 2018. International co-operation also continued with Mid-Sweden University by completing wind tunnel measurements in Östersund for a study of slipstreaming in cross-country skiing in March, May and October 2018. The measurements applied measuring systems developed by the sports technology unit, and a machine vision application for automatically calculating the angle of a ski pole that was developed by CSC at CEMIS (the LIIKUTPA project). Research work on Nordic ski sports has continued in close partnership with the Finnish Research Institute for Olympic Sports (KIHU), the Finnish ski and biathlon associations, the Finnish Olympic Committee and the Vuokatti-Ruka Sports Academy.

Project Operations

A significant portion of operations at the Vuokatti sports technology unit comprises R&D projects implemented with national and international partners. The principal national partners have been the other CEMIS participants (MITY, KAMK, VTT and CSC), Vuokatti Sports Institute and the Municipality of Sotkamo. Major ongoing projects in 2018 included „new biathlon feedback systems” (funded by Regional Council of Kainuu/ERDF), the CEMIS joint project „new technologies and services for sport and wellbeing – LIIKUTPA” (funded by Regional Council of Kainuu/ERDF), „virtual coach for health and wellbeing professionals” (funded by Business Finland/ERDF) and a project to prepare for top-level competition implemented in partnership with the Finnish ski and biathlon associations.

The joint LIIKUTPA project completed at the end of 2018 was implemented by all of the CEMIS partners and co-ordinated by the University of Jyväskylä. In addition to co-ordinating the team project, the work of the sports technology unit at the University of Jyväskylä focused on realising the prototypes of replicable sensor integrations for ski poles and roller skis, developing sensor solutions for biathlon, further development of ski testing methods, and simulating the environment of the PyeongChang Olympics sprint competition skiing route in the Vuokatti ski laboratory. Athlete testing development work conducted jointly with CSC focused on determining whether more automated machine vision can be used for business analysis. The findings of the LIIKUTPA project are reported in greater detail in an earlier section describing the CEMIS Development programme.

The „New Biathlon Skiing Feedback Systems and Investment in a Ski Treadmill” project incorporated the biathlon rifle sensor solutions developed in the LIIKUTPA project into the development of a shooting test conducted under laboratory conditions, and developed shooting range measurement technology to support daily training. One important part of the project was the construction of a new ski



Figure 8.2. The new University of Jyväskylä ski laboratory constructed as part of an ERDF project at Snowpolis in Vuokatti.

laboratory at Snowpolis in Vuokatti, with investment in a new roller ski treadmill and a portable breath gas analyser (Figure 8.2).

All of the CEMIS organisations were involved in the “Virtual coach for health and wellness professionals” project. The Virtual Coach application seeks to serve as a personal trainer without the immediate presence of professionals, and to forecast the impact of the quantity and type of physical activity on performance or body composition. The project was divided into three sections, of which the first designed the Virtual Coach concept and began work to develop a prototype application (Figure 8.3). KAMK was responsible for technical implementation of the prototype, and the University of Jyväskylä took charge of calculating the development of physical capacity based on scientific criteria. The second project section engaged the sports technology unit in conducting a pilot study in which dynamic equilibrium served as one measure for monitoring physical capacity, with comparisons made to other physical or physiological variables. The project sought to promote the message of physical capacity monitoring as part of comprehensive health and wellness monitoring. The work also included developing a dynamic equilibrium test with VTT-MIKES. The third project section assigned the University of Oulu measurement technology unit in Kajaani to develop a field-operable biosensor measurement readout device to monitor such aspects as stress (cortisol) or nutritional balance from saliva. The project ended in August 2018.

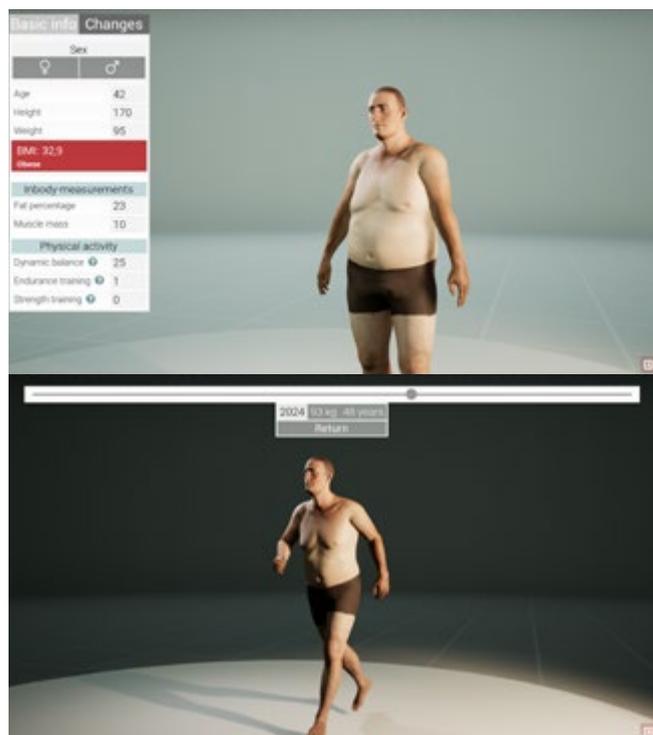


Figure 8.3. The prototype Virtual Coach application.

The Finnish Ski and Biathlon associations also launched a joint project in 2018 to prepare for top-level competition, seeking to enhance ski maintenance and coaching at the next Olympics. The University of Jyväskylä sports technology unit will direct the practicalities of this project, which supported preparations for the Seefeld World Ski Championships over the year. The overall project work will focus on

building a database, testing and polishing skis, and prior condition mapping and race time activities in top-level competition. Measures to improve ski maintenance will apply ski and pole testers developed in partnership with CEMIS.

Master's Degree and Doctoral Education Programmes

Vuokatti provides facilities for completing Master's thesis work in high standard research projects or in partnership with private businesses. These theses primarily focus on biomechanics, sports physiology, or the theory of coaching and testing. The topics of such theses may include aids for human activity and movement, development and quality assurance of testing and training equipment for top-level sports and fitness, and processing of biosignals in the context of sports biology. The Master's degree programme in sports technology has been financed by the Faculty of Sport and Health Sciences at the University of Jyväskylä and the Municipality of Sotkamo since 2014, with continued financing currently guaranteed until 2023. The University of Jyväskylä and the Municipality of Sotkamo concluded an agreement at Vuokatti on 27 February 2018 to continue the current co-operation and financing agreement for the next five years.

Four individuals completed a Master's degree in sports sciences during 2018, bringing the all-time total number of graduates from the sports technology Master's degree programme to 74. One new job for graduates was reported during the year. The total number of new jobs reported over the entire period of the Master's programme is 99, of which 37 were in the Kainuu region. Seven new students joined the Master's programme in autumn 2018. The next student intake will begin studies in autumn 2020. Six doctoral dissertations were in preparation, one of which was completed during the year in partnership with KIHU, the Finnish Research Institute for Olympic Sports („Technical Determinants of Competitive Rifle Shooting Performance” by Simo Ihalainen). Three ongoing doctoral dissertations are due for completion in partnership with a foreign university, and two are based solely at the University of Jyväskylä. A total of five doctoral dissertations have been completed in Vuokatti over the years.

Operations of CSC – IT Center for Science in Kajaani

CSC operations at CEMIS in 2018 focused on developing artificial intelligence applications for athlete testing, solutions for mass processing of sensitive data, and data-driven modelling of industrial process measurement data. This work has enabled CSC to develop its own measuring technology expertise and appreciation of the field, while improving the ability of other operators to use data analytics in their own operations. Another significant project in the field of data analytics has been the joint CSC and KAMK Data Analytics Accelerator, which has helped businesses in the region to deploy analytics and facilitated the launch of artificial intelligence training.

CSC – IT Center for Science is a national centre for high-performance computing, data analytics and information networks that provides services to universities, research institutes, the public sector and businesses. CSC is a non-profit limited company that is owned by the Finnish government and higher education institutions and managed by the Ministry of Education and Culture. Since joining CEMIS in August 2016 CSC has focused on applying and disseminating expertise on data analytics and artificial intelligence within the CEMIS network. In 2018 CSC participated in the LIIKUTPA and BIOMIT sub-projects, and also co-ordinated a joint Data Analytics Accelerator project with

KAMK. A disused BULL supercomputer donated by CSC to KAMK for educational purposes was officially commissioned at an inauguration on 11 December 2018.

During 2018 CSC planned significant expansions of its Kajaani data centre as part of the DL2021 project of the Ministry of Education and Culture. The process involves reconfiguring the computing cluster, supercomputer and storage environment. The first planned installations were completed in Kajaani during 2019. Towards the end of 2018 CSC also convened the European LUMI consortium, which agreed to finance a world-class supercomputer in Kajaani and



Figure 9.1. The CSC data centre in Kajaani is a global leader in energy conservation and cost-effectiveness, using 100 per cent hydropower with minimal cooling energy required due to the climate in Kajaani.

was accordingly able to participate in competitive tendering under the EuroHPC programme (<https://eurohpc-ju.europa.eu>). Kajaani was chosen in 2019 as one of three locations for European supercomputers. Future radical increases in computing capacity located in Kajaani have also led to a moderate increase in staffing at the CSC facility, and have naturally aroused significant interest and collaboration potential globally. EuroHPC has also given CSC a mandate to seek extensive business use for the supercomputing environment, with CEMIS providing one excellent avenue for this work.

Machine Vision Applications for Sport and Exercise

The work of CSC has included developing an application in the context of the LIIKUTPA project that automatically determines the angle of a competition skier's pole while training on an athlete testing treadmill. The angle of the ski pole in turn determines the propulsion component that drives the skier forward. The application uses machine vision analysis of a video image. It has been implemented in a Qt development environment and includes application-specific settings with an interactive graphical user interface, and a batch processing feature built into the Coachtech system. The final tool has been used for analysing varying test materials filmed with a range of cameras. Development of the application continued over the year, with measurement specialists from Vuokatti assisting in enhancing accuracy of recognition.

Besides this application, preliminary trials were also conducted to adapt human pose estimation for the needs of sports science (Figure 9.2). Modelling approaches included the use of advanced deep learning methods based on neural networks, such as Facebook's DensePose. Body segment recognition, ski jumping, sledding and a dynamic balance test developed at Vuokatti have been studied as potential new applications.

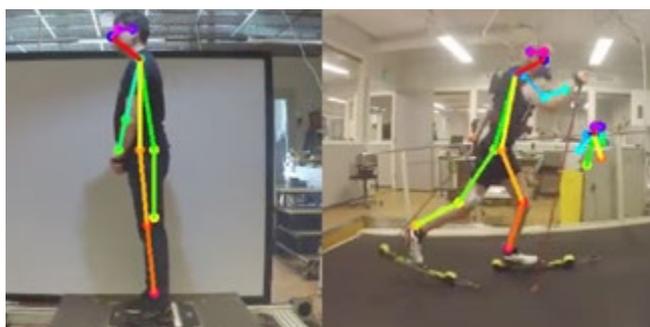


Figure 9.2. The work of CSC on the LIIKUTPA project included a study of the use of human pose estimation for modelling the posture of an athlete in dynamic balance tests and treadmill.

Sensitive Health Data

Processing sensitive data is a key issue in studies of health and wellness, as the details of an individual's health must be handled with the assurance of confidentiality. On the other hand, many services related to personal health and wellness already operate on

the cloud nowadays. Harmonising sensitive data and cloud services has accordingly assumed key significance in the field of health and wellness research.

As part of its work on the LIIKUTPA project in 2018 CSC has developed a pilot environment for bulk processing of sensitive data. The environment is based on widely used Apache Spark technology and provides the security required for processing confidential information. A report of this work was prepared and the resulting solutions will be implemented in the HYTELI project, which began in early 2019.

Analytics Bring Added Value to Industrial Measurement

Successful development of industrial measurement systems requires a diversity of measurement technology to justify large-scale investment in systems through broadly-based benefits. CSC conducted a data analytics consultation in the context of the BIOMIT project, exploring the prospects for identifying metal by-products in data collected by the mining industry, and thereby significantly increasing the value of data collection. CSC also conducted two NIR (Near Infrared) sensor data analyses with a view to reducing the number and cost of measurements required. Data analytical methods enable commensurable adaptation of various measurement results and a resolution of data disruptions to enhance visibility of the basic phenomena.

Accelerating the Deployment of Analytics in Businesses

CSC co-ordinated a joint data analytics accelerator project with KAMK, providing support to businesses in the area seeking to deploy analytics and helping to launch artificial intelligence training. Over the year this project established business contacts and identified needs by visiting enterprises, explaining the opportunities of data analytics and reviewing business requirements in face-to-face meetings.

The accelerator project also supported the work of KAMK in preparing to start a unique form of artificial intelligence training. These preparations have enabled KAMK to launch its new training programme in 2019.

Publications

In 2018 a total of 24 international peer-reviewed academic publications and 23 professional and conference publications were produced at CEMIS. In addition to that, CEMIS was also the background to two doctoral theses, five Master's theses, eight University of Applied Sciences Master's degrees and 112 theses in science, engineering and business administration.

Doctoral Dissertations

Panjan, Peter (2018) Innovative microbioreactors and microfluidic integrated biosensors for biopharmaceutical process control. Ph.D thesis. University of Oulu Graduate School; University of Oulu, Faculty of Medicine. Acta Universitatis Oulu. D 1453. (dissertation formally presented on 22 November 2018)

Ihalainen, Simo (2018) Technical determinants of superior rifle shooting technique. Ph.D thesis. University of Jyväskylä. (dissertation formally presented on 9 July 2018)

Diploma and Master's Theses

Molkoselkä, Eero (2018) Digitaalisten hologrammien esikäsittely (in Finnish). Diploma thesis. University of Oulu. 54 p.

Nikola-Määttä, Sanna (2018) Kestävyyden ja tehokkuuden seuranta lyhyellä aikavälillä (in Finnish). Master's thesis. University of Jyväskylä. 69 p.

Ollonen, Petri (2018) Maastohiihdon Rukan maailmancupin kilpailun 2015 biomekaaninen kilpailuanalyysi (in Finnish). Master's thesis. University of Jyväskylä. 97 p.

Sippola, Niina (2018) Plyometrisen ja konsentrisen nopeusvoimaharjoittelun vaikutukset lihasjännekompleksin toimintaan ja rakenteeseen (in Finnish). Master's thesis. University of Jyväskylä. 68 p.

Köykkä, Miika (2018) Biathlon standing shooting performance, shooting technical components and postural balance at rest and during a race simulation. Master's thesis. University of Jyväskylä. 77 p.

Academic Publications

Lladó Maldonado S., Panjan P., Sun S., Rasch D., Sesay A. M., Mayr T., Krull R. (2018) A fully online sensor-equipped, disposable multiphase microbioreactor as a screening platform for biotechnological applications. *Journal of Biotechnology & Bioengineering*. (DOI: 10.1002/bit.26831)

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Kanyathare B., Kuivalainen K., Rätty J., Silfsten P., Bawuah P., Peiponen K-E. (2018) A prototype of an optical sensor for the identification of diesel oil adulterated by kerosene. *Journal of the European optical society: rapid publications*, 3, 1990-2573.

Taskila S., Ahokas M., Sotaniemi V-H., Mäki M., Malinen H-L., Jaakkola M., Virpiranta H., Tanskanen J. (2018) Conversion of potato peel waste to single cell protein by an acidophilic fungus. *Journal of Water Resource and Protection*, 10, 522-532.

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CEMIS sites are located in the Kainuu region, Finland, in the town of Kajaani and Vuokatti leisure centre. We are far away from hectic city life, but instead we have a safe and clean living environment supported by the 4 seasons of northern Finland. We offer excellent possibilities for recreational sports in winter and summer. If you are interested in working or studying in CEMIS, do not hesitate to contact us at info@cemis.fi.



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