

# DEPARTMENT OF INTELLIGENT SYSTEMS

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*The Department of Intelligent Systems develops new methods and techniques for intelligent computer systems, with applications in the areas of the information society, computer science and informatics, and network communication systems. The main research areas are ambient intelligence, computational intelligence, agent and multi-agent systems, language and speech technologies, electronic and mobile health, and smart cities. The department closely collaborates with the Faculty of Computer and Information Science of the University of Ljubljana in the joint research programme "Artificial Intelligence and Intelligent Systems". The department also continuously collaborates with industry and contributes to the inclusion of intelligent systems in products and services.*



Head:  
**Prof. Matjaž Gams**

Intelligent systems simulate intelligence so that a typical user perceives them as truly intelligent. In reality, these systems use complex mechanisms and implement them on digital platforms to imitate human behaviour by exploiting raw, exponentially growing computer power. This field is somewhat broader than artificial intelligence, but both are rapidly growing worldwide and are enabling the development of the information society.

**Ambient intelligence** is a research field aiming to introduce technology into our everyday environment in a friendly way that is undemanding for the user. The main area where the department applies methods of ambient intelligence is health. We finished the H2020 project **CrowdHealth**, whose objective was to mine health data to help craft better public-health policies. The method for predicting physical stature, which we developed in the project in collaboration with the Faculty of Sports of the University of Ljubljana, is now being integrated into the SLOFit application. SLOFit is a national surveillance system for the physical and motor development of children and youth.

The H2020 project **WellCo** created a virtual coach to advise older users on wellbeing and health. For this coach we developed methods to monitor nutrition with sensors and questionnaires, and to recognize the users' emotions from their voice. The H2020 project **Insension** is helping people with severe intellectual disability use digital services. We developed methods for the interpretation of their inner state using video from cameras and other sensors. In the Flemish-Slovenian project **STRAW**, whose objective is stress recognition from sensor data and analysis of stressors in the workplace, we started data collection with a sensing wristband and a mobile application. In the AAL project **CoachMyLife** we will help seniors with memory impairment perform everyday tasks. To this end, we developed methods to monitor nutrition and hydration with a sensing wristband and computer vision. We started the H2020 project **COVIRNA**, whose objective is to develop a diagnostic test for cardiovascular patients with COVID-19. We did other research on COVID-19, mainly a thorough analysis of factors affecting the spread of the disease in different countries using machine learning. We won an international **competition** on recognizing cooking activities from sensor data Cooking Activity Recognition Challenge. We also got to the second stage of the XPrize Pandemic Response Challenge, a competition in predicting COVID-19 infections and prescribing countermeasures (the competition continues in 2021). We finished **doctoral research** on methods for intelligently adjusting the operation of sensors to reduce energy consumption without sacrificing the sensing quality. We also finished doctoral research on the fusion of classical and deep machine learning for mobile health and behaviour monitoring with wearable sensors. We have ongoing doctoral research on the contact-free sensing of physiological signals and states.

In the field of **agent and multi-agent systems**, the key research areas are the development of intelligent autonomous systems for managing smart cities and smart homes, and intelligent healthcare support systems. This consists of developing new algorithms, methods and approaches by introducing artificial intelligence into computer systems. In 2020 we started a series of new projects. In the Interreg Italy-Slovenia programme, we

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**We completed the project Multi-objective optimization for transparent tunnel design. The task was to design and implement a flexible method able to find a set of near-optimal tunnel routes where both the constraints and objectives for the route are chosen by the user.**

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*Figure 1: To improve the planning of tool manufacturing for injection molding, we developed a software solution to predict the duration of machining operations that relies on extracting features from 3D tool drawings and machine learning of predictions based on these features.*

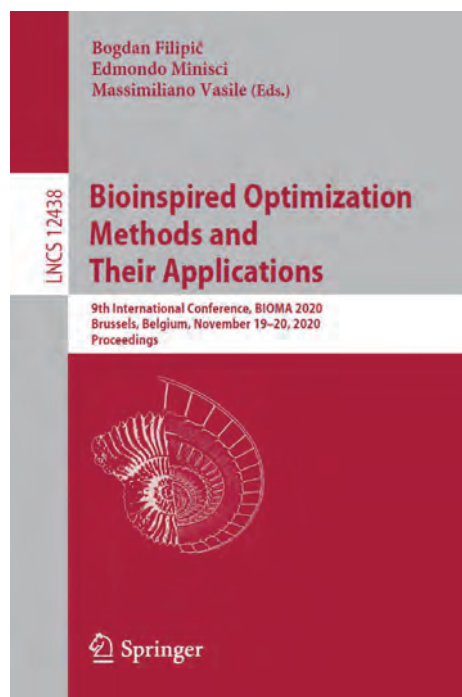


Figure 2: We coorganized the 9th International Conference on Bioinspired Optimization Methods and Their Applications, BIOMA 2020, that was held virtually on 19-20 November 2020. The conference proceedings were published by Springer in the series Lecture Notes in Computer Science.

launched the **Insieme** project, which is developing a platform for electronic and mobile health (EMH), which will offer Slovenian and Italian users a range of online services, including the possibility of talking online with specialists in the field of EMH. We also developed a number of new and innovative devices and solutions to support elderly and chronic patients at home, where, among other things, we already developed a smartwatch for the elderly, but we are now transferring it to mobile phones. In addition to improvements to the system for an autonomic reaction after a fall, we also introduced a system for predicting falls, which uses the bracelet to determine the stability of walking and, in the event of deterioration, to warn of the risk of falling. For the **H2020 Urbanite smart cities** project, we developed a first prototype of a system that simulates traffic in Bilbao. The project includes four European cities: Amsterdam, Helsinki, Bilbao and Messina. The system will ultimately enable city managers to validate and identify the best mobility policies and measures. As part of the European **ERA PerMed BATMAN** project, where the theme is the Acne Inversa disease research, we developed a prototype that enables data input, display and processing. Partners-physicians from European countries will be able to enter data on patients in order to create a sufficiently large database for processing using AI methods. In the framework of the **ROBKONCEL** project, in cooperation with Gorenje and Unior, we developed a prototype of an intelligent system for comprehensive quality control in production with a reconfigurable robotic control cell and an intelligent process-control system. For the company **Comland**, we developed an intelligent system for managing the application in natural language. For the company **NiceLabel** we developed a system for intelligent webmail sorting, which determines the scope based on content and helps in creating responses.

**Computational intelligence** is a study of stochastic search, optimization and learning methods, inspired by biological and physical systems. Research in this area at the Department of Intelligent Systems focuses on evolutionary computation and optimization. We study evolutionary algorithms for multi-objective optimization, their acceleration through parallel computing and surrogate models, constraint handling in multi-objective optimization, visualization of optimization results, methodology of algorithm benchmarking, and their applicability in science and engineering. In 2020, we completed several industrial projects based on this expertise. In

collaboration with the INEA company, we developed a **computer system to schedule flexible offers for electricity production and consumption** aimed at reducing the mismatch between the available and the needed electrical energy. The system uses mixed-integer linear programming as an optimization methodology. Testing at several pilot installation sites in various European countries showed the system is capable of producing high-quality schedules of flexible offers under strict time requirements. We also completed the project **Multi-objective optimization for transparent tunnel design** for the XLAB company. The task was to design and implement a flexible method able to find a set of near-optimal tunnel routes where both the constraints and objectives for the route are chosen by the user. We solved this task by encoding tunnel routes with clothoids and using a multi-objective evolutionary

algorithm to find trade-off solutions. This method proved to be efficient in solving problems with objectives as diverse as minimal costs, best technical characteristics and minimal environmental impacts. Finally, we participated in two **Key Enabling Technologies for Clean Production (KET4CP)** projects for small manufacturing enterprises Plamtex INT and MPT. The first project was devoted to the improved planning of tool manufacturing for injection moulding where the task was to predict the duration of machining operations needed to manufacture the tools, and the developed solution relies on extracting features from 3D tool drawings and the machine learning of predictions based on these features. The goal of the second project was to design a machine-vision system to monitor the quality of moulded plastic products, and our role was to construct models for classifying the products into quality classes and assess their accuracy.

In the field of **speech and language technologies** we work on speech synthesis, semantic analysis of text and question answering. Together with the companies Alpineon and Amebis we developed a new, high-quality speech synthesizer eBralec (<http://ebralec.si/>). Its fourth version was released this year. The synthesizer is improved in terms of both comprehensibility and natural perception of the speech. A new high-quality female voice was added. The software package has more than a thousand subscribers and is an indispensable tool for blind and visually-impaired

**We used machine learning to perform probably the most thorough analysis to date of factors affecting the spread of COVID-19 in different countries. We focused on the early period before countermeasures overshadowed other factors.**

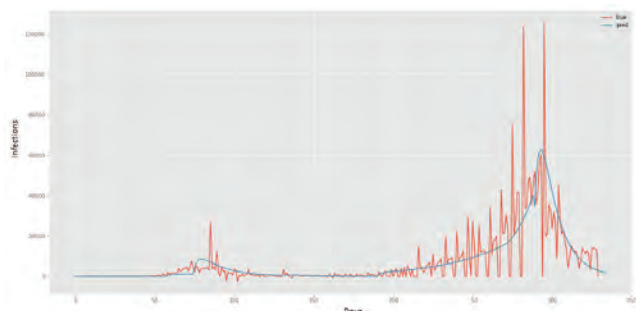


Figure 3: We participated in the "XPRIZE: Pandemic response challenge" competition, where we were tasked with estimating the number of COVID-19 infections. In the figure we show our prediction for France, for the year 2020, compared to the actual infection values.

users (it is the “official” speech synthesizer of the Slovenian Association for the Blind and Visually Impaired) and people with reading impairments (the Bravo association). For these users, eBralec is free of charge and can be ordered at the Library for the Blind and Visually Impaired (<http://www.kss-ess.si/ebralec-sintetizator-govora-slovenskega-jezika/>). eBralec is also an integral part of the DarsTraffic+ application, which provides traffic information, while its server version has been used by the National and University Library since 2017. It has been reading news on the renewed Delo (national daily newspaper) website since this year. We also developed a service of speech synthesis for mobile devices (<http://dis.ijs.si/dyslex/>), which is free for anyone to use. We completed successfully the CityVOICE project: “Speech Technologies with Advanced Language Resources”. We continue to work on the AudiBook project: “Education accessibility through a digital audio library for the blind and visually impaired”.

The 23rd International Multiconference Information Society – IS 2020 ([is.ijs.si](http://is.ijs.si)) took place at the Jožef Stefan Institute from October 5 to 9, 2020. It consisted of 8 independent conferences with 160 presentations. Four conference awards were presented: for lifetime achievements (“Donald Michie and Alan Turing” award) to prof. dr. Lidija Zadnik Stirn, for current achievements in the field of information society to the ACM Bober Competition Program Committee, and the information strawberry (Laboratory for Bioinformatics, Faculty of Computer and Information Science, University of Ljubljana) and lemon (unresponsiveness in the development of the electronic health record) for the best and worst public information-society services.

Together with the University of Strathclyde we organized the 9th International Conference on Bioinspired Optimization Methods and Their Applications (BIOMA 2020) that was held virtually on 19-20 November 2020. BIOMA is a conference series providing an opportunity for the research community in bio-inspired optimization to present recent achievements and discuss new ideas in the field. This year the conference programme consisted of the invited talks by Prof. Gabriela Ochoa on recent advances in local optima and search trajectory networks and Prof. Enrique Alba on algorithms for smart cities, and 24 presentations of regular papers. The conference proceedings were published by Springer in the series Lecture Notes in Computer Science (LNCS).

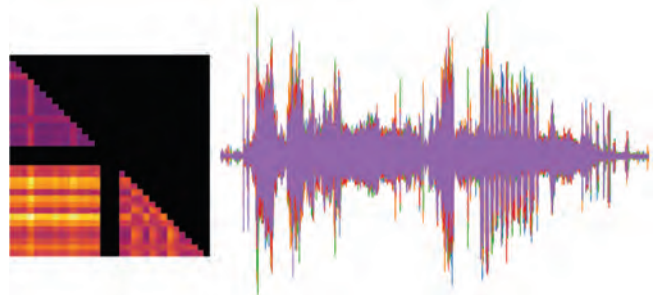


Figure 4: We implemented a tool-wear assessment based on sensor data from a production process. The figure shows a comparison of vibrations at the initial treatments (i.e., after tool replacement) with the vibrations at the final treatments (i.e. before the next tool replacement).



Figure 5: In 2020, the 23rd International Multiconference Information Society – IS 2020 ([is.ijs.si](http://is.ijs.si)) consisted of eight separate conferences. Four awards were handed out, of which the Lifetime Achievement Award (recognition of “Donald Michie and Alan Turing”) was presented to Prof. Dr. Lidija Zadnik Stirn.

## Some outstanding publications in the past year

1. Gjoreski, M., Janko, V., Slapničar, G., Mlakar, M., Reščič, N., Bizjak, J., Drobnič, V., Marinko, M., Mlakar, N., Luštrek, M., Gams, M. Classical and deep learning methods for recognizing human activities and modes of transportation with smartphone sensors. *Information Fusion*, 2020, 62, 47-62.
2. Álvarez-García, J. A., Cvetković, B., Luštrek, M. A survey on energy expenditure estimation using wearable devices. *ACM Computing Surveys*, 2020, 53 (5), 1-35.
3. Gjoreski, M., Gradišek, A., Budna, B., Gams, M., Poglajen, G. Machine learning and end-to-end deep learning for the detection of chronic heart failure from heart sounds. *IEEE Access*, 2020, 8, 20313-20324.
4. Varelas, K., El Hara, O. A., Brockhoff, D., Hansen, N., Manh Nguyen, D., Tušar, T., Auger, A. Benchmarking large-scale continuous optimizers: The bbob-largescale testbed, a COCO software guide and beyond. *Applied Soft Computing*, 2020, 97, part A, 106737-1-106737-13
5. Zupančič, J., Filipič, B., Gams, M. Genetic-programming-based multi-objective optimization of strategies for home energy-management systems. *Energy*, 2020, 203, 117769-1-117769-15

## Awards and appointments

1. Stefan Kalabakov, Simon Stankoski, Nina Reščič, Andrejaana Andova, Ivana Kiprijanovska, Vito Janko, Martin Gjoreski, Mitja Luštrek: SHL Challenge – Sussex-Huawei Locomotion and Transportation Recognition Challenge, 3rd Place Award, virtual, Dr Hristijan Gjoreski, University of Sussex (UK) & Ss. Cyril and Methodius University (MK), Dr Lin Wang, University of Sussex (UK), Prof. Daniel Roggen, University of Sussex (UK), Dr Kazuya Murao, Ritsumeikan University (JP), Dr. Tsuyoshi Okita, Kyushu Institute of

- Technology (JP), Mathias Ciliberto, University of Sussex (UK), Paula Lago, Kyushu Institute of Technology (JP), method for recognition of locomotion activity from smartphone sensors
2. Clément Picard, Vito Janko, Nina Reščič, Martin Gjoreski, Mitja Luštrek: The Cooking Activity Recognition Challenge 1st Place Award, virtual / Kitakyushu, Japan, ABC Conference, method for recognition of cooking activities with sensors
  3. Maj Smerkol: Best paper award at People and Environment, 23rd International Multiconference Information Society, IS 2020, Ljubljana, Jožef Stefan Institute, Traffic Simulation Software in the Context of Mobility Policy Support System
  4. Tea Tušar: Best Paper award at Human-Computer Interaction in Information Society, 23rd International Multiconference Information Society, IS 2020, Ljubljana, Jožef Stefan Institute, Interactive visualization of the Slovenian budget with the Sankey diagram

## Organization of conferences, congresses and meetings

1. 36th Slovenian Workshop on Nature-Inspired Algorithms, AVN, Maribor, 29 September 2020 (virtual)
2. 9th International Conference on Bioinspired Optimization Methods and Their Applications, BIOMA 2020, Brussels, Belgium, 19–20 November 2020 (virtual)
3. 37th Slovenian Workshop on Nature-Inspired Algorithms, AVN, Ljubljana, 2 December 2020 (virtual)
4. UbiTtention 2020: 5th International Workshop on Smart & Ambient Notification and Attention Management, UbiComp 2020, Cancun, Mexico, 12 September 2020 (virtual)
5. Slovenian Conference on Artificial Intelligence 2020 (subconference of the 23rd International Multiconference Information Society (IS 2020)), Ljubljana, 6–7 October 2020
6. 23rd international multiconference Information Society, IS2020, Ljubljana, 5–9 October 2020
7. GECCO Job Market at the Genetic and Evolutionary Computation Conference, GECCO 2020, Cancun, Mexico, 10 July 2020 (virtual)
8. On-Body Sensor Networks workshop (OBSN 2020) at the International Conference on Embedded Wireless Systems and Networks (EWSN 2020), Lyon, France, 17 February 2020
9. 23. International Multiconference, IS 2020, Ljubljana, 5–9 October 2020, independent conferences:
  - Professional Ethics
  - Human-Computer Interaction in Information Society
  - Data Mining and Data Warehouses
  - Cognitive Science
  - People and Environment
  - International Technology Transfer Conference
  - Slovenian Conference on Artificial Intelligence
  - Education in Information Society

## Patents granted

1. Alexander Gilenson, Boštjan Kaluža, Oz Eyal, System and method for automated detection of anomalies in the values of configuration item parameters, US10635557 (B2), US Patent Office, 28. 04. 2020.
2. Alexander Gilenson, Boštjan Kaluža, Oz Eyal, System and method for incident root cause analysis, US10691522 (B2), US Patent Office, 23. 06. 2020.

## INTERNATIONAL PROJECTS

1. ERASMUS+; Audio Library for Visually Impaired; Education Accessibility through a Digital Audio Library for the Blind and Visually-Impaired  
Dr. Tomaž Šef  
European Commission
2. COST CA17129: CardioRNA - Catalysing Transcriptomics Research in Cardiovascular Disease  
Dr. Mitja Luštrek  
Cost Association Aisbl
3. H2020 - CrowdHEALTH; Collective Wisdom Driving Public Health Policies  
Dr. Mitja Luštrek  
European Commission
4. H2020 - INSENSION; Personalized Intelligent Platform Enabling Interaction with Digital Services to Individuals with Profound and Multiple Learning Disabilities  
Dr. Mitja Luštrek  
European Commission
5. H2020 - WellCo; Wellbeing and Health Virtual Coach

- Dr. Mitja Luštrek  
European Commission
6. H2020 - PlatformUptake.eu; Assessing the State of Art and Supporting an Evidence-Based Uptake and Evolution of Open Service Platforms in the Active and Healthy Ageing Domain  
Prof. Matjaž Gams  
European Commission
  7. H2020 - URBANITE; Supporting the decision-making in URBAN transformation with the use of disruptive Technologies  
Prof. Matjaž Gams  
European Commission
  8. H2020 - COVIRNA; A Diagnostic Test to improve Surveillance and Care of COVID-19 Patients  
Dr. Mitja Luštrek  
European Commission
  9. Development of AI Methods for Monitoring Affective States Using Unobtrusive Sensors  
Prof. Matjaž Gams  
Slovenian Research Agency

- Multi-Objective Optimization for Artificial Intelligence Systems in Industry  
Prof. Bogdan Filipič  
Slovenian Research Agency

## RESEARCH PROGRAMME

- Artificial Intelligence and Intelligent Systems  
Dr. Mitja Luštrek

## R&D GRANTS AND CONTRACTS

- Disentangling the sources and context of daily work stress: a comprehensive real-time modelling study using wearables and technological detections  
Dr. Mitja Luštrek
- Food for future - F4F  
Dr. Mitja Luštrek  
Ministry of Education, Science and Sport
- Italian-Slovenian Ecosystem for Electronic and Mobile Health  
Prof. Matjaž Gams  
Regione Autonoma Friuli Venezia Giulia, Direzione
- SI4CARE  
Dr. Mitja Luštrek  
Ministry of Economic Development and Technology
- CoachMyLife  
Dr. Mitja Luštrek  
Ministry of Public Administration
- ML-Aml: Application of Machine Learning Methods to Ambient Intelligence: Psychosocial Stress and Behaviour analysis  
Prof. Matjaž Gams  
Public Scholarship, Development, Disability and Maintenance Fund of the Republic of Slovenia
- BATMAN: Biomolecular Analyses for Tailored Medicine in Acne iNversa  
Prof. Matjaž Gams  
Ministry of Education, Science and Sport
- Reimbursement of costs of scientific publications in golden open access for 2019, 2020  
Prof. Matjaž Gams  
Slovenian Research Agency
- 23rd International Multiconference Information Society 2020, IS 2020, Ljubljana, Slovenia, 5 October 2020 - 9 October 2020  
Prof. Matjaž Gams
- CLD - Cognitive Load Dataset  
Dr. Mitja Luštrek  
Fraunhofer-Institut für Integrierte

## VISITOR FROM ABROAD

- Prof. dr Boris Naujoks, Beate Breiderhoff, Cologne University of Applied Sciences (TH Köln), Gummersbach, Germany, 9–11 March 2020

## STAFF

### Researchers

- Dr. Erik Dovgan
- Prof. Bogdan Filipič
- Prof. Matjaž Gams, Head**
- Asst. Prof. Anton Gradišek
- Dr. Mitja Luštrek
- Dr. Miha Mlakar
- Dr. Tomaž Šef
- Asst. Prof. Tea Tušar

### Postdoctoral associates

- Dr. Carlo Maria De Masi
- Dr. Vito Janko
- Dr. Boštjan Kaluža\*
- Dr. Rok Piltaver\*
- Dr. Aleš Tavčar\*

### Postgraduates

- Andrejaana Andova, B. Sc.
- Dr. *Martin Gjoreski, on leave 01.12.20*
- Tine Kolenik, B. Sc.
- Tomaž Kompara\*, B. Sc.
- Dr. Jana Krivec\*
- Alina Luminita Machidon, B. Sc., left 18.10.20*
- Gašper Slapničar, B. Sc.
- David Susič, B. Sc.

- Aljoša Vodopija, B. Sc.
- Jernej Zupančič, B. Sc., left 04.09.20*

### Technical officers

- David Golob, B. Sc., left 01.04.20*
- Primož Kocuvan, B. Sc.
- Anže Marinko, B. Sc.
- Maj Smerkol, B. Sc.
- Jakob Valič, B. Sc.
- Zdenko Vuk, B. Sc.

### Technical and administrative staff

- Jani Bizjak, B. Sc.
- Matej Cigale, B. Sc.
- Vesna Koricki, B. Sc.
- Mitja Lasič
- Liljana Lasič
- Junoš Lukan, B. Sc.
- Blaž Mahnič, B. Sc.
- Nina Reščič, B. Sc.
- Marijeka Šprah, B. Sc., left 01.09.20*
- Lana Zemljak

Note:

\* part-time JSI member

## BIBLIOGRAPHY

### ORIGINAL ARTICLE

- Juan Antonio Álvarez-García, Božidara Cvetković, Mitja Luštrek, "A survey on energy expenditure estimation using wearable devices", *ACM computing surveys*, 2020, **53**, 5, 91.
- Matej Madeja, Jaroslav Porubán, Veljko Pejović, Martin Gjoreski, "Observation of students behaviour in programming courses with an automated testing platform at differently geolocated universities: a case study", *Acta electrotechnica et informatica*, 2020, **20**, 3, 39-47.
- Martin Gjoreski, Tine Kolenik, Timotej Knez, Mitja Luštrek, Matjaž Gams, Hristijan Gjoreski, Veljko Pejović, "Datasets for cognitive load inference using wearable sensors and psychological traits", *Applied sciences*, 2020, **10**, 11, 3843.
- Konstantinos Varelas, Ouassim Ait El Hara, Dimo Brockhoff, Nikolaus Hansen, Duc Manh Nguyen, Tea Tušar, Anne Auger, "Benchmarking large-scale continuous optimizers: the bbbob-largescale testbed, a COCO software guide and beyond", *Applied soft computing*, 2020, **97**, a, 106737.
- Luka Pirker, Anton Gradišek, Bojana Višič, Maja Remškar, "Nanoparticle exposure due to pyrotechnics during a football match", *Atmospheric environment*, 2020, **233**, 117567.
- Jana Krivec, Matej Guid, "The influence of context on information processing", *Cognitive processing*, 2020, **21**, 2, 167-184.
- Jernej Zupančič, Bogdan Filipič, Matjaž Gams, "Genetic-programming-based multi-objective optimization of strategies for home energy-management systems", *Energy*, 2020, **203**, 117769.

8. Martin Gjoreski, Anton Gradišek, Borut Budna, Matjaž Gams, Gregor Poglajen, "Machine learning and end-to-end deep learning for the detection of chronic heart failure from heart sounds", *IEEE access*, 2020, **8**, 20313-20324.
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11. Gizem Gültekin Várkonyi, Anton Gradišek, "Data protection impact assessment case study for a research project using artificial intelligence on patient data", *Informatica*, 2020, **44**, 4, 497-505.
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13. Larissa Bolliger, Junoš Lukan, Mitja Luštrek, Dirk De Bacquer, Els Clays, "Protocol of the STRess at Work (STRAW) project: how to disentangle day-to-day occupational stress among academics based on EMA, physiological data, and smartphone sensor and usage data", *International journal of environmental research and public health*, 2020, **17**, 23, 8835.
14. Octavian-Mihai Machidon, Aleš Tavčar, Matjaž Gams, Mihai Duguleană, "CulturalERICA: a conversational agent improving the exploration of European cultural heritage", *Journal of cultural heritage*, 2020, **41**, 152-165.
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24. Maciej Dzieżyc, Martin Gjoreski, Przemysław Kazienko, Stanisław Saganowski, Matjaž Gams, "Can we ditch feature engineering? End-to-end deep learning for affect recognition from physiological sensor data", *Sensors*, 2020, **20**, 22, 6535.
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5. Matjaž Gams, "Izumiranje Slovencev in drugih narodov", In: *Okrogla miza kadrovska vrzel v Sloveniji: zakaj v Sloveniji primanjkuje ljudi v delovni starosti, 30. januar 2020, Ljubljana*, zbornik, Inštitut dr. Antona Korošca, 2020, 30-32.
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