EPIC: An Energy-Efficient, High-Performance
GPGPU Computing Research Infrastructure
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Abstract—The pursuit of many research questions requires massive computational resources. State-of-the-art research in physical processes using simulations, the training of neural networks for deep learning, or the analysis of big data are all dependent on the availability of sufficient and performant computational resources. For such research, access to a high-performance computing infrastructure is indispensable.

Many scientific workloads from such research domains are inherently parallel and can benefit from the data-parallel architecture of general purpose graphics processing units (GPGPUs). However, GPGPU resources are scarce at Norway's national infrastructure.

EPIC is a GPGPU enabled computing research infrastructure at NTNU. It enables NTNU's researchers to perform experiments that otherwise would be impossible, as time-to-solution would simply take too long.

I. INTRODUCTION

The end of Dennard's scaling left computing systems across all domains increasingly power constrained. Specialized hardware in the form of accelerators emerged as alternatives to perform computations more energy-efficient. Specifically, general-purpose, graphic-processing units (GPGPUs) became increasingly popular as a means to accelerate programs in high-performance computing (HPC) and artificial intelligence.

GPGPUs devote more compute resources to accelerate data-parallel applications by sacrificing resources that improve sequential program performance, rendering them more energy-efficient for data-parallel application domains. Nowadays, GPGPUs are significantly employed in High-Performance Computing (HPC) systems to meet performance demands while maintaining power constraints. For example, nine of the ten most powerful supercomputers in the world rely on GPGPUs for their computational power [175]. Furthermore, eight of the top ten most energy-efficient supercomputers in the world rely on GPGPUs [61].

The EPIC research infrastructure is a project between the Department of Computer Science and the IT Division at the Norwegian University of Science and Technology (NTNU) that aims at providing a GPGPU compute platform. EPIC is a part of the NTNU Idun computing cluster [76], which provides a high-availability and professionally administered compute platform for NTNU. Idun combines compute resources of individual shareholders to create a cluster for rapid testing and prototyping of HPC software. Currently, EPIC constitutes 48% of the total number of nodes in the IDUN cluster and 100% of the GPGPU resources.

EPIC is with its 158 GPGPUs one of Norway’s largest GPGPU enabled computational infrastructures. Norwegian national infrastructure has a very limited number of GPGPU resources, e.g., Saga [152] has only 32 NVIDIA Tesla P100 [133] and Colossus [39] has 32 much older NVIDIA Tesla K20.

II. THE IDUN CLUSTER

The Idun cluster is a Tier-2 [63] research cluster at NTNU meant as a stepping stone for the national infrastructure and serves as a platform for rapid testing and prototyping of HPC software, research into energy-efficient computing, and GPU-aided simulations and design-space exploration.

Currently, Idun consists of 73 nodes connected by two networks: one ethernet network and one high-throughput and low-latency InfiniBand (IB) network. The 1 Gb/s ethernet network serves as an administration and provisioning network, while the IB network is used for inter-node communication. The IB network is a mix of FDR (4x lanes each of 14 Gb/s) and EDR (4x lanes each of 25 Gb/s), as shown in Figure 1. Each node is connected with either FDR or EDR, resulting in 56 Gb/s or 100 Gb/s per node, respectively. The individual IB switches are connected in a tree structure with 3xFDR links between each switch, resulting in 168 Gb/s inter-switch connection speed.

Idun’s storage is provided by two storage arrays and a Lustre parallel distributed file system [110]. The storage arrays, one serves as Lustre metadata target (MDT) and one as Lustre object storage target (OST), are complemented with two Lustre metadata servers (MDS) and two object storage servers (OSS). The MDT and MDSs store the namespace data of the file system, such as filenames, directories, access permissions and file layouts, while the OST and OSSs store the file data. Together, the IB network and the Lustre file system, provide the means to efficiently transfer data to the compute resources, enabling an effortless scaling of the cluster in terms of nodes and/or GPUs.

III. THE EPIC RESEARCH INFRASTRUCTURE

The EPIC research infrastructure consists of five distinct investments (see Table 1), each with a distinct purpose:

The original EPIC consists of eight nodes with two NVIDIA P100 GPUs and focused on energy-efficient computing research such as energy efficient resource management for latency-critical cloud services [132].
**EPIC2** consists of 19 GPGPU nodes, each equipped with two NVIDIA P100 GPUs. These nodes complement EPIC1 and provide raw computational GPU power. These nodes are used for research in 3D object identification [187], physical simulations (e.g., nanomagnet ensemble dynamics modeled in MuMAX [189] and flatspin [87]), and deep learning.

**EPIC3** consists of five big-memory nodes, each equipped with two NVIDIA V100 GPUs. These nodes are meant for AI research that requires massive training sets, and therefore need more main memory.

**EPIC4** is an extension of EPIC2 providing another 26 GPUs for raw computational power. It consists of one node with ten V100 32 GiB GPUs and two nodes with eight V100 32 GiB GPUs. In addition, the big-memory GPUs (32 GiB instead if 16 GiB) enable larger working set sizes beneficial for 3D object identification and large AI models.

**EPIC5** is a further extension that adds 68 GPUs distributed across 11 nodes as well as four Xilinx Alveo U250 field programmable gate array (FPGA) accelerator cards distributed across two nodes. The primary use of the FPGA accelerators are to support computer architecture research using, e.g., FireSim [93].

Even though the the purpose and configuration of EPIC1-5 differ, all 158 GPGPUs can be accessed as one distributed resource for massive GPGPU performance.

**IV. RESEARCH OUTCOME**

The EPIC cluster has been an indispensable resource for a wide range of research, e.g., efficient resource management, nanomagnetic modeling, 3D object identification, etc. Below is a non-exhaustive list of published articles that relied on EPIC to produce their results:

- Energy-efficient resource management for latency-critical cloud services [132].
- Emergent computation on magnetic ensembles [85], [111], [88], [87], [141], [142], [143], [86].
- Bit-serial matrix multiplication acceleration [180], [120].
- Intermediate representation (IR) for optimizing compilers [147].
- Nano-scale structures of aluminum alloys [37], [38], [35].
- Management of Internet of things (IoT) devices [128].
- Numerical modeling of renewable energy production and storage [181], [183], [182], [184], [83], [82].
- Bankruptcy prediction using machine learning [130], [195].
- Interest rate and treasury securities modeling [196], [197].
- Isogeometric analysis of acoustic scattering [190], [192], [191].
- Framework for wind field predictions [177].
- 3D object identification [187], [188].
- Computational fluid dynamics [137], [15], [99], [17], [16].
- Shear viscosity analysis [144], [145].
- Molecular dynamics simulations [55].
- Modeling of convection flows [104].
- Genetic association studies [65], [2].
- Behavior detection in echograms [113].
- Autoignition-stabilized flames [56].
- Speculative side-channel mitigations [154], [157], [102].
5. Modeling polymeric nanofibres [25, 24, 23]
6. Emission modeling [100]
7. Modeling systemic circulation [26]
8. Text processing using deep learning [178]
9. Digital twins [170]
10. Neocortex encoding structure [122]
11. Analytical models [176]
12. Population activity in grid cells [53]
13. Cardinality constraints [75]
14. Neuroscience [121]
15. Computer graphics [171]
16. Hyperspectral imaging [45]
17. Performance profiling [59, 60, 58]
18. Computational linguistics [98]
19. Maintenance optimization [139, 140]
20. Uncertainty analysis [198]
21. Superconducting machines [69]
22. Ship inspection [199]
23. Object anonymization [74]
24. Spatial design [11]
25. Nonimaging optics [91]
26. Numerical modeling of heat transfer [42]
27. Macromolecular crowding [27]
28. Yield Curve Modeling [197]
29. Stochastic search [119]
30. Computer Security [156]
31. And on many more topics [19, 12, 70, 117, 131, 95, 204, 411, 44, 21, 172, 179, 205, 92, 116, 124, 125, 33, 73, 162, 126, 153, 31, 158, 48, 94, 118, 150, 201, 13, 84, 96, 186, 32, 109, 97]

A. PhD Theses

The cluster has been used to produce results for at least the following PhD theses:

1. Emil Christiansen, “Nanoscale characterisation of deformed aluminium alloys”, 2019 [36].
2. Pablo Miguel Blanco, “Coupling of binding and conformational equilibria in weak polyelectrolytes. Dynamics and charge regulation of biopolymers in crowded media.”, 2020 [28].
3. Ranik Raen Wahlstrøm, “Financial data science for exploring and explaining the ever-increasing amount of data”, 2021 [194].
4. Luis Alfredo Moctezuma “Towards Universal EEG systems with minimum channel count based on Machine Learning and Computational Intelligence”, 2021 [123].
5. Eivind Bering, “Stretching, breaking, and dissolution of polymeric nanofibres by computer experiments”, 2021 [22].
6. Jan Inge Hammer Meling, “Hydrogen assisted crack growth in iron: a simulations approach”, 2021 [115].
7. Christos Sakalis, “Rethinking Speculative Execution from a Security Perspective”, Uppsala University, 2021 [155].
8. Johannes Haydahl Jensen, “Reservoir computing in-materio: Emergence and control in unstructured and structured materials”, 2021 [89].
9. Ronja EM Wedegårtner, “Highways up the mountains: Trails as facilitators for redistribution of plant species in mountain areas”, 2022 [200].
10. Björn Gottschall, “Time-Proportional Performance Analysis for Out-of-Order Processors”, 2024 [57].
11. Anders Strømberg, “Design and control of artificial spin ice”, 2024 [169].

B. MSc Thesis Projects

The cluster is also used as an educational resources where students can run their simulations and produce results for their thesis projects.

1. André Håland and Bjørn Birkeland, “Exploring data assignment schemes when training deep neural networks using data parallelism”, 2020 [64].
2. Jørgen Boganes, “Accelerating Object Detection for Agricultural Robotics, 2020 [29].
3. Daniel Ørnes Halvorsen, “Studies of turbulent diffusion through direct numerical simulation”, 2020 [67].
4. Bjørn Magnus Valberg Iversen, “Combining Hyperband and Gaussian Process-based Bayesian Optimization”, 2020 [61].
5. Runar Ask Johannessen, “Aggregation of Speaker Embeddings for Speaker Diarization”, 2020 [90].
6. Siv-Marie McDougall, “Fluorohectorite as a CO2 adsorbent: a DFT and DFTB study”, 2020 [114].
7. M. Tarlton, Y. Roudi, and N. Bulso, “Novel Model Selection Criterion for Inference of Ising Models”, 2021 [173].
8. Richard Bachmann, “Performance Modeling of Finite Difference Shallow Water Equation Solvers with Variable Domain Geometry”, 2021 [20].
9. Frikk Hald Andersen and Eirik Dahlen, “Sesame Street Pays Attention to Pro-Eating Disorder”, 2021 [9].
10. Martin Rebne Farstad, “Understanding the Key Performance Trends of Optimized Iterative Stencil Loop Kernels on High-End GPUs”, 2021 [46].
11. Einar Aasli, “Numerical Simulation of Fluid-Structure Interaction”, 2021 [4].
12. Klara Schlüter and Jon Riege, “Stochastic Multiplicative Learning and Predictive Safety Filtering for Floating Offshore Wind Turbine Control”, 2021 [52].
13. Karoline Bonnerud, “Write Like Me: Personalized Natural Language Generation Using Transformers”, 2021 [30].
14. Michael Tarlton, “Novel Model Selection Criterion for Inference of Ising Models”, 2021 [174].
15. Anja Rosvold From and Ingvild Unander Nteland, “Fake News Detection by Weakly Supervised Learning: A Content-Based Approach”, 2021 [50].
16. Didrik Salve Galteland, “Exploring Self-supervised Learning-based Methods for Monocular Depth Estimation in an Autonomous Driving Setting”, 2021 [52].
17. Veibøsm Malmin and HalvorØdegård Teigen, “Reinforcement Learning and Predictive Safety Filtering for Floating Offshore Wind Turbine Control”, 2021 [112].
18. Marthe Strand Haltbakk, “Kinetic Monte Carlo simulation of the early precipitation stages in Al-Mg-Si alloys using Cluster Expansion methods for energy barrier modelling”, 2021 [66].
19) Andreas Herlesund Søgnen, “Numerical analysis of finned-tubes and finned-tube bundles”, 2021 [161].
20) Aurora Grefsrud, “Efficiency of IllustrisTNG in modeling galaxy properties”, 2021 [62].
21) Joakim Olsen, “Measuring Summary Quality using Weak Supervision”, 2021 [138].
22) Varun Loomba and Jan Erik Olsen and Kristian Etienne Einarsrud, “Modelling of Furnace Tapping with Uniform and Non-Uniform Porosity Distribution”, 2021 [108].
23) Lars Andreas Hustad Lervik, “Orientation and Projection Center Refinement for EBSD Indexing in Python”, 2021 [106].
24) Vemund Fredriksen and Svein Ole Matheson Sevle, “Pulmonary Tumor Segmentation Utilizing Mixed-Supervision in a Teacher-Student Framework”, 2021 [49].
25) Halvor Bakken Smødås, “ASSIST: Accuracy-driven Sampling Strategies for Improved Supervised Training”, 2021 [160].
26) Robin Christian Staff, “What a Twist-Using Deep Neural Networks to Generate Plot Twists”, 2021 [165].
27) Håkon Sørensen Bøckman, “Locating sheep in the high-lands with aerial footage and a lightweight algorithm system”, 2021 [163].
28) Alexander Michael Staff, “An Empirical Study on Cross-data Transference of Adversarial Attacks on Object Detectors”, 2021 [164].
29) Jon Steinar Folstad, “Transformer Pre-Trained Language Models and Active Learning for Improved Blocking Performance in Entity Matching”, 2021 [37].
30) Christian Ziegenhahn Jensen and Espen Storhaug, “The Perfect Rap Lyrics-AI Generated Rap Lyrics That Are Better Than Lyrics from Existing Popular and Critically Acclaimed Rap Songs”, 2021 [84].
31) Jostein Lillemoøkken and Martin Hermansen, “Improving Performance of Autonomous Driving in Simulated Environments Using End-to-End Approaches”, 2021 [107].
32) Michael Moen Allport and Jonas Sandberg, “Q-PRM-A QoS Aware Resource Manager for Colocated Services”, 2021 [6].
33) Vilde Roland Arntzen, “Detecting Norwegian Abusive Language in Social Media with Transformer-based Models”, 2021 [13].
34) Magnus Midtbø Kristiansen, “Proving Theorems Using Deep Learning”, 2021 [101].
35) Emil Alvar Myhrø, “Bayesian optimal experimental design for studying synaptic plasticity”, 2021 [129].
36) Ingebrigt Nygård and Sebastian Vittersø, “Improved Sheep Detection-Modifying YOLOv5 to accurately detect grazing sheep in UAV imagery”, 2022 [136].
37) Fabian Vakhidi, “Pose Estimation with Convolutional Neural Networks”, 2022 [185].
38) Andrés Javier Estévez Fernández, “Combining question answering models with transformer-based generative conversational agents”, 2022 [43].
39) Jonas Strand Aasberg, “Machine Learning using High Resolution Zivid Point Clouds on a High Performance Cluster”, 2022 [1].
40) Jenny Bleken Hellerud, “AI and Emotions in Perfect Harmony-Recognising Emotions in Music using CQT Spectrograms and Multi-output Regression”, 2022 [71].
41) Eivind Aksnes Rebnord, “Generating Audio from Sample Librarie”, 2022 [146].
42) Hallvard Størhaug, “Impact of Low Resolution IR Images in Drone Based Sheep Detection”, 2022 [166].
43) Christopher Michael Vibe, “Practical Reservoir Computing & Echo State Property Metrics”, 2022 [193].
44) Fredrik Almås, “Bottom-detection in Doppler Velocity Logs using Recurrent Neural Networks on an embedded platform”, 2022 [7].
45) Angqi Zhao, “Lithium cations mobility in a coarse-grained polymer embedded with Lennard Jones particles using non-equilibrium molecular dynamics”, 2022 [206].
46) André Storhaug, “Secure Smart Contract Code Synthesis with Transformer Models”, 2022 [167].
47) Preben Gjelsvik, “Optical Properties of Intermediate Band Ca6FeN5 and Related Materials: A Density Functional Theory Study”, 2023 [54].
48) Kristin Frøystein, “Scanning precession electron diffraction data analysis of in-situ precipitate evolution in an Al-Mg-Si-Cu alloy”, 2023 [51].
49) Tobias Meyer Andersen, “Performance Modeling of a Load-Balanced FDM Wave Equation Solver on Heterogeneous Clusters”, 2023 [10].
50) Ole Joachim Arnesen Asen, “Small languages and big models-Using ML to generate social media content for training purposes”, 2023 [3].
51) Alexander Michael Ås, “A Norwegian Whisper Model for Automatic Speech Recognition”, 2023 [18].
52) Karoline Lillevestre Langli, “Sentiment Analysis of Customer Emails Using BERT”, 2023 [103].
53) John Askeland Lauvud, “Investigating Speculative Side-Channel Protection”, 2023 [105].
54) Ulrik Bernhardt Danielsen, “A step toward model selection in unsupervised clustering of animal behavior”, 2023 [40].
55) Velte Kristaver Widnes Harnes, “Exploring Efficient Accelerator-Core Integration Strategies: A Case Study of BISMO in Chipyard”, 2023 [68].
56) Andreas Rønnestad, “Evaluation of Safety-Oriented Metrics For Object Detectors”, 2023 [151].
57) Karoline Seljevoll Herleiksplass, “Enhancing Sleep-Wake Detection Using Deep Learning and Optimal Channel Selection from High-Density EEG”, 2023 [72].
58) Christopher Strøm, “Towards robust and flexible point-object multi-target tracking using transformer neural networks”, 2023 [168].
59) Marcus Stensby Young, “Improving Memory Scheduling of an Out-of-Order Core”, 2023 [203].
60) Clemens Martin Müllner, “Physics informed neural networks in radial load flow calculations”, 2023 [127].

V. CONCLUSION

EPIC is a multi-million investment by the Department of Computer Science in collaboration with the IT Division to provide GPGPU resources for NTNU’s researchers. The large
number of GPGPUs enable research studies to be performed at a scale that otherwise would be impossible to conduct. Thus, EPIC’s computational resources help NTNU’s researchers to stay competitive and produce state-of-the-art results.

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REFERENCES

[1] J. S. Aasberg, “Machine learning using high resolution zivid point clouds on a high performance cluster,” Master’s thesis, NTNU, 2022.
[2] K. Aase, H. Jensen, and S. Muff, “Genomic estimation of quantitative genetic parameters in wild admixed populations,” bioRxiv, 2021.
[3] O. J. A. Aasen, “Small languages and big models-using ml to generate social media content for training purposes,” Master’s thesis, NTNU, 2023.
[4] E. Aasi, “Numerical simulation of fluid-structure interaction,” Master’s thesis, Norwegian University of Science and Technology, 2021.
[5] P. Aimoniotis, A. B. Kvalsvik, M. Sjølander, and S. Kaxiras, “ReCon: Efficient detection, management, and use of non-speculative information leakage,” in Proceedings of the 56th Annual International Symposium on Microarchitecture, 2023.
[6] M. M. Allport and J. Sandberg, “Q-PRM-A QoS aware resource manager for colocated services,” Master’s thesis, NTNU, 2021.
[7] F. Almås, “Bottom-detection in doppler velocity logs using recurrent neural networks on an embedded platform,” Master’s thesis, NTNU, 2022.
[8] AMD, “Amd® EPYC® 7543,” https://www.amd.com/en/products/cpu/amd-epyc-7543.
[9] F. H. Andersen and E. Dahlen, “Sesame street pays attention to protonating disorder,” Master’s thesis, Norwegian University of Science and Technology, Jun. 2021.
[10] T. M. Andersen, “Performance modeling of a load-balanced fmdm flow equation solver on heterogeneous clusters,” Master’s thesis, NTNU, 2023.
[11] S. Anyosa, J. Eidsvik, and O. Pizarro, “Adaptive spatial designs minimizing the integrated bernoulli variance in spatial logistic regression models-with an application to benthic habitat mapping,” Computational Statistics & Data Analysis, vol. 179, p. 107643, 2023.
[12] A. I. Aria, B. Holmedal, T. Mánik, and K. Martinhsen, “A full-field crystal plasticity study on the bauchinger effect caused by non-shearable particles and voids in aluminium single crystals,” Metals, vol. 14, no. 4, p. 424, 2024.
[13] V. R. Arntzen, “Detecting norwegian abusive language in social media with transformer-based models,” Master’s thesis, NTNU, 2021.
[14] A. Arosemena, H. Ali, and J. Solsvik, “Characterization of cortical structures in a stirred tank,” Physics of Fluids, vol. 34, no. 2, 2022.
[15] A. A. Arosemena, H. I. Andersson, and J. Solsvik, “Turbulent channel flow of generalized newtonian fluids at a low reynolds number,” Journal of Fluid Mechanics, vol. 908, p. A43, 2021.
[16] A. A. Arosemena, R. Andersson, H. I. Andersson, and J. Solsvik, “Effects of shear-thinning rheology on near-wall turbulent structures,” Journal of Fluid Mechanics, vol. 925, 2021.
[17] A. A. Arosemena and J. Solsvik, “Velocity–vorticity correlations and the four-layer regime in turbulent flow of generalized newtonian fluids,” European Journal of Mechanics - B/Fluids, vol. 91, pp. 1–8, 2022. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0997554621001345.
[18] A. M. Ås, “A norwegian whisper model for automatic speech recognition,” Master’s thesis, NTNU, 2023.
[19] J. C. Aspheim, K. Aase, G. H. Bolstad, H. Jensen, and S. Muff, “Bayesian marker-based principal component ridge regression—a flexible multipurpose framework for quantitative genetics in wild study systems,” bioRxiv, pp. 2024–06, 2024.
[20] R. Bachmann, “Performance modeling of finite difference shallow water equation solvers with variable domain geometry,” Master’s thesis, Norwegian University of Science and Technology, 2021.
[21] J. Benestad, J. A. Krzywda, E. van Nieuwenburg, and J. Danon, “Efficient adaptive bayesian estimation of a slowly fluctuating overhauser field gradient,” arXiv preprint arXiv:2309.15014, 2023.
[22] E. Bering, “Stretching, breaking, and dissolution of polymeric nanofibers by computer experiments,” Ph.D. dissertation, Norwegian University of Science and Technology, 2021.
[23] E. Bering, D. Bedefaux, S. Kjelstrup, A. S. de Wijn, I. Latella, and J. M. Rubi, “A legendre–fenchel transform for molecular stretching energies,” Nanomaterials, vol. 10, no. 12, p. 2355, 2020.
[24] E. Bering, S. Kjelstrup, D. Bedefaux, J. M. Rubi, and A. S. de Wijn, “Entropy production beyond the thermodynamic limit from single-molecule stretching simulations,” The Journal of Physical Chemistry B, vol. 124, no. 40, pp. 8909–8917, 2020.
[25] E. Bering, J. Torstensen, A. Lervik, and A. S. de Wijn, “Computational study of the dissolution of cellulose into single chains: the role of the solvent and agitation,” Cellulose, vol. 29, no. 3, pp. 1365–1380, 2022.
[26] N. L. Bjørndalsbakke, J. T. Sturdy, D. R. Hose, and L. R. Hellevik, “Parameter estimation for closed-loop lumped parameter models of the systemic circulation using synthetic data,” Mathematical Biosciences, 2021.
[27] P. M. Blanco, S. Madurga, J. L. Garcés, F. Mas, and R. S. Dias, “Influence of macromolecular crowding on the charge regulation of intrinsically disordered proteins,” Soft Matter, vol. 17, no. 3, pp. 655–669, 2021.
[28] P. M. Blanco et al., “Coupling of binding and conformational equilibria in weak polyelectrolytes. dynamics and charge regulation of biopolymers in crowded media.” Ph.D. dissertation, Universitat de Barcelona, 2020.
[29] J. Boganes, “Accelerating object detection for agricultural robotics,” Master’s thesis, Norwegian University of Science and Technology, 2020.
[30] K. Bonnerud, “Write like me: Personalized natural language generation using transformers,” Master’s thesis, Norwegian University of Science and Technology, 2021.
[31] J. Borgelt, J. Sicacha-Parada, O. Skarpaas, and F. Verones, “Native range estimates for red-listed vascular plants,” Scientific Data, vol. 9, no. 1, p. 117, 2022.
[32] A. Carduillac and M. Ludvigsen, “A communication interface for multilayer cloud computing architecture for low cost underwater vehicles,” IFAC-PapersOnLine, vol. 55, no. 14, pp. 77–82, 2022.
[33] L. Cheng, R. Khalitov, T. Yu, J. Zhang, and Z. Yang, “Classification of long sequential data using circular dilated convolutional neural networks,” Neurocomputing, vol. 518, pp. 50–59, 2023.
[34] L. Cheng, T. Yu, R. Khalitov, and Z. Yang, “Self-supervised learning for dna sequences with circular dilated convolutional networks,” Neural Networks, vol. 171, pp. 466–473, 2024.
[35] E. Christiansen, I. Ringdalen, R. Bjørge, C. Marioara, and R. Homestad, “Multislice image simulations of sheared needle-like precipitates in an Al-Mg-Si alloy,” Acta Materialia, vol. 124, pp. 8909–8917, 2020.
[36] E. Christiansen, I. Ringdal, R. Bjørge, C. Marioara, and R. Homestad, “Influence of macromolecular crowding on the charge regulation of intrinsically disordered proteins,” Soft Matter, vol. 17, no. 3, pp. 655–669, 2021.
[37] E. Christiansen, I. Ringdal, R. Bjørge, C. Marioara, and R. Homestad, “Multislice image simulations of sheared needle-like precipitates in an Al-mg-si alloy,” Journal of Microscopy, vol. 279, no. 3, pp. 267–279 [Online]. Available: https://onlinelibrary.wiley.com/doi/abs/10.1111/jmi.12901.
[38] E. Christiansen, “Nanoscale characterisation of deformed aluminium alloys,” Ph.D. dissertation, Norwegian University of Science and Technology, 2019.
[39] E. Christiansen, C. D. Marioara, B. Holmedal, O. S. Hopperstad, and R. Homestad, “Nanoscale parameterization of sheared β’ precipitates in a deformed Al-mg-si alloy,” Scientific reports, vol. 9, no. 1, pp. 1–11, 2019.
[40] E. Christiansen, C. D. Marioara, I. G. Ringdalen, R. Bjørge, B. Holmedal, O. S. Hopperstad, and R. Homestad, “Detailed investigation of the shearing mechanism of β’ precipitates in Al-mg-si alloys,” in MATEC Web Conference. EDP Sciences, 2020.
[41] “Colossus GPU support,” https://www.uio.no/en/units/it/infrastructure/infrastructure_networking/flow_of_turbulent_flow_of_generalized_newtonian_fluids,” European Journal of Mechanics - B/Fluids, vol. 91, pp. 1–8, 2022. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0997554621001345.
[42] E. Christiansen, “A step toward model selection in unsupervised clustering of animal behavior,” Master’s thesis, NTNU, 2023.
[183] K. J. Vachaparambil and K. E. Einarsrud, “Numerical simulation of bubble growth in a supersaturated solution,” *Applied Mathematical Modelling*, 2020.

[184] K. J. Vachaparambil and K. E. Einarsrud, “On sharp surface force model: effect of sharpening coefficient,” *Experimental and Computational Multiphase Flow*, 2020.

[185] F. Vakhidi, “Pose estimation with convolutional neural networks.” Master’s thesis, NTNU, 2022.

[186] B. I. van Blokland and T. Theoharis, “An indexing scheme and descriptor for 3d object retrieval based on local shape querying,” *Computers & Graphics*, vol. 92, pp. 55–66, 2020.

[187] B. I. van Blokland and T. Theoharis, “Radial intersection count image: a robust 3D shape descriptor,” *Computers & Graphics*, vol. 91, pp. 118–128, Oct. 2020, https://doi.org/10.1016/j.cag.2020.07.007

[188] B. I. van Blokland and T. Theoharis, “Partial 3D object retrieval using local binary QUICCI descriptors and dissimilarity tree indexing,” *Computers & Graphics*, vol. 100, pp. 32–42, 2021.

[189] A. Vansteenkiste, J. Leliaert, M. Dvornik, M. Helsen, F. Garcia-Sanchez, and B. Van Waeyenberge, “The design and verification of MuMax3,” *AIP advances*, vol. 4, no. 10, p. 107133, 2014.

[190] J. V. Venås, “Acoustic scattering in an isogeometric framework,” Ph.D. dissertation, NTNU, 2019.

[191] J. V. Venås and T. Kvamsdal, “Isogeometric boundary element method for acoustic scattering by a submarine,” *Computer Methods in Applied Mechanics and Engineering*, vol. 359, 2020. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S0045782519305559

[192] J. V. Venås, T. Kvamsdal, and T. Jenserud, “Isogeometric analysis of acoustic scattering using infinite elements,” *Computer Methods in Applied Mechanics and Engineering*, vol. 335, pp. 152 – 193, 2018. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S004578251830094X

[193] C. M. Vibe, “Practical reservoir computing & echo state property metrics,” Master’s thesis, NTNU, 2022.

[194] R. R. Wahlstrøm, “Financial data science for exploring and explaining the ever-increasing amount of data.” Ph.D. dissertation, Norwegian University of Science and Technology, 2021.

[195] R. R. Wahlstrøm and F. F. Helland, “Konskursprediksjon for norske selskaper—en analyse ved maskinlæringsteknikker og tradisjonelle statistiske metoder,” Master’s thesis, NTNU, 2016.

[196] R. R. Wahlstrøm, F. Paraschiv, and M. Schürle, “A comparative analysis of parsimonious yield curve models with focus on the nelson-siegel, Svensson and Bliss models,” http://dx.doi.org/10.2139/ssrn.3600955, May 2020.

[197] R. R. Wahlstrøm, F. Paraschiv, and M. Schürle, “A comparative analysis of parsimonious yield curve models with focus on the nelson-siegel, Svensson and Bliss versions,” *Computational Economics*, pp. 1–38, 2021.

[198] C. Wang, T. S. Nord, G. Ziemer, and G. Li, “Towards uncertainty and sensitivity analysis for modal parameters identification during ice–structure interaction,” *Ocean Engineering*, vol. 277, p. 114224, 2023.

[199] K. Wiik, I.-M. Høyvik, E. Unneberg, T. L. Jensen, and O. Swang, “Unimolecular decomposition reactions of picric acid and its methylated derivatives—A DFT study,” *The Journal of Physical Chemistry A*, vol. 126, no. 17, pp. 2645–2657, 2022.

[200] Xilinx, “Xilinx © U250 data center acceleration card,” https://www.xilinx.com/products/boards-and-kits/alveo/u250.html, Dec. 2021.

[201] Z. Zhang, J. I. Ceballos, A. Nysveen, and T. S. Haugan, “Comparison of core loss models considering the impact of PWM switching,” in *2023 IEEE 6th Student Conference on Electric Machines and Systems (SCEMS)*. IEEE, 2023, pp. 1–7.

[202] Z. Zhang, J. I. Ceballos, A. Nysveen, and T. S. Haugan, “Computation of core losses in electrical steel laminations with impacts of normal flux and PWM switching considered,” *IEEE Transactions on Magnetics*, 2023.

[203] A. Zhao, “Lithium cations mobility in a coarse-grained polymer embedded with lennard jones particles using non-equilibrium molecular dynamics,” Master’s thesis, NTNU, 2022.