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Title	Description	Tasks	Required knowledge
Development of Capacitive Fluidic Sensors with 3D Printed Channels and Direct-Ink-Written Electrodes	This project proposes the design, fabrication, and experimental evaluation of capacitive fluidic sensors that integrate additively manufactured microfluidic channels with electrodes patterned using direct ink writing. The objective is to create a compact, low-cost sensing platform whose capacitance varies in a dependable way when aqueous solutions are present inside a 3D-printed channel. Electromagnetic design methods will be used to anticipate how electrode area, spacing, overlap, and channel wall thickness determine the sensor capacitance and its sensitivity to fluid permittivity and conductivity. Basic analytical capacitor approximations will be assessed alongside electrostatic simulations, enabling iteration of electrode geometries before printing any devices. A key initial phase is to become proficient with the laboratory tools needed for digital design, 3D printing (Bambu Lab H2C), conductive-ink deposition (Voltera Nova), and electrical testing. CAD software will define channel shapes, electrode patterns, and fixture features that can be produced on a desktop 3D printer and a direct-ink-writing platform. Process settings such as nozzle size, print speed, ink viscosity, and curing temperature will be recorded to ensure electrode conductivity and adhesion are repeatable across devices. Following a review of capacitance measurement approaches, the AD7150 evaluation board will be	Become proficient with the tools needed to design and fabricate the capacitive fluidic sensor. Delivering a working capacitive fluidic sensor prototype. Review of capacitance measurement techniques and utilize the AD7150 evaluation board for capacitance measurements. Use saline water with controlled salt concentration to characterize the performance of the fabricated sensors. Expected deliverables include a documented design workflow, a set of printed and functionalized prototypes, measurement results for saline water filled channels, and a written report comparing simulation outcomes with experimental data.	

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Camera based collision avoidance methods for unmanned aerial vehicles, simulator environment development	The task is to develop a simulator environment to support the algorithmic and hardware development, based on an existing simulator system. The improvement of the parts of the current system is necessary, like the rendering engine (Ogre vs FlightGear, test with new versions), testing and communication with image processing hardwares (GPU, FPGA). A very important part is also to write a comprehensive documentation on the setup. Unmanned Aerial Vehicles, UAV, FPGA, GPU, collision avoidance, video and image processing	Adapt and expand an existing simulator environment to facilitate both algorithmic and hardware development for the project. Upgrade components of the current system, including evaluating and possibly updating the rendering engine by comparing Ogre vs FlightGear and testing with newer versions. Implement and test communication interfaces between the simulator and image processing hardware, such as GPUs and FPGAs. Write comprehensive documentation detailing the simulator setup, including hardware and software configurations. Conduct thorough testing to validate the efficacy and compatibility of the enhanced simulator environment with the intended algorithmic and hardware developments.	C++, Matlab, OpenGL
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Application of deep learning methods for improvement of self-organizing maps in multidimensional time series representation	Self-Organizing Maps (SOM, Kohonen Network, etc.) are capable of representing the input space of the training set by a map. However, the best initialization of the network and the dimensional reduction of the input data have to be investigated. The hypothesis is that by applying deep learning methods such as augmentation of SOM, or Time adaptive SOM (TASOM) the representation of large scale and multidimensional time-series data can be improved. The objective is to determine an efficient structure and learning methods that are capable of representing such time series and can perform classification or clustering with high precision.	Investigate optimal initialization methods for Self-Organizing Maps (SOM, Kohonen Network) to best represent the input space of the training set. Explore techniques for dimensional reduction of the input data to enhance the performance of the SOM. Evaluate the potential improvements in representing large-scale and multidimensional time-series data by applying deep learning methods like Augmentation of SOM or Time Adaptive SOM (TASOM). Determine an efficient network structure that is capable of accurately representing the time-series data in question. Develop and test learning methods aimed at achieving high-precision classification or clustering based on the optimized SOM structure.	Programming skills (C++ or Python), Basics of Machine Learning
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Self-motion and orientation estimation for aircraft	The goal of the project is to augment the capabilities of the widespread GPS/IMU-based self-motion estimation algorithms with information available from onboard camera images. The first part is to do a comprehensive literature review on the state-of-the-art and then develop new algorithms for the task. Also, it is important to run tests to determine the statistical properties of these algorithms. The test is run either on videos rendered by the simulator or also on flight videos. Preliminary algorithms, scientific papers, the simulator, and flight videos are available for the job. Unmanned Aerial Vehicles, UAV, sensor fusion, collision avoidance, video and image processing	Conduct a comprehensive literature review on the state-of-the-art GPS/IMU-based self-motion estimation algorithms and techniques that integrate onboard camera images. Develop new algorithms that augment GPS/IMU-based self-motion estimation with information extracted from onboard camera images. Assess the statistical properties of the newly developed algorithms to ensure reliability and accuracy. Execute tests on the new algorithms using videos rendered by the available simulator, as well as real-world flight videos to validate performance. Compile findings, including test results and algorithmic approaches, into scientific papers for dissemination and further study.	C++, Matlab, OpenCV, OpenGL
Laboratory Automation in Systems Biology	Microbial communities are extremely important in our daily lives both physiologically and from a biotechnological stance. In the systems biology group, we study the interactions of microbes and especially yeast strains. In our experimental work, the application of automated methods is crucial. We have liquid handling systems and a motorized microscope at our disposal. Our students can join our projects and take part in the development of high throughput and automated protocols. We would be happy for students interested in robotics, automation and high-throughput methods to join the group.	Get a deeper understanding of the literature and chosen methods. Take part in the development of automated methods or data processing workflows. Take part in the testing process and live experiments.	Basic programming skills or openness to learn

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Laboratory Automation in Systems Biology	Microbial communities are extremely important in our daily lives both physiologically and from a biotechnological stance. In the systems biology group, we study the interactions of microbes and especially yeast strains. In our experimental work, the application of automated methods is crucial. We have liquid handling systems and a motorized microscope at our disposal. Our students can join our projects and take part in the development of high throughput and automated protocols. We would be happy for students interested in robotics, automation and high-throughput methods to join the group.	Get a deeper understanding of the literature and chosen methods. Take part in the development of automated methods or data processing workflows. Take part in the testing process and live experiments.	Basic programming skills or openness to learn
Development of an open source colony-picking robot	Colony picking is a frequent task in microbiology where individual colonies are sampled and transferred in a liquid medium for further culturing. In this project, we will be developing a colony-picking robot to automate this otherwise tedious task. The goal is to develop a system that can be either used directly by the user or can be integrated in a laboratory automation platform for high-throughput sampling. The student will take part in the development of a hardware/software prototype depending on her/his interests.	1. Literature review of existing solutions and other projects that can be used for the project 2. Develop hardware components for the colony-picking robot 3. Take part in the mechanical design of the future prototype 4. Develop a Python framework to control the robot.	Know the basics of cad modelling, electronics and programming in a high level programming language (eg. Python or C++)

Development of An Open-source Microscope Stage	In modern microscopy systems motorised microscope stages are crucial. Without motorized stages imaging of a large number of samples in high-throughput experiments or large areas is unimaginable. Unfortunately commercially available motorized stages have a prohibitive pricing and their precision usually far exceeds what is generally needed. Luckily, today with the spread of hobby 3D printers, laser engravers and CNC machines mechanical components and electrical components are readily available (stepper motors/drivers, rail systems, microcontrollers). Although there are several open-source stages in the literature their integration into image acquisition platforms is still problematic [1-2]. The task of the prospective student will be to take part in the development of a prototype and/or to write software to control the microscope stage. [1] Openstage: A Low-Cost Motorized Microscope Stage with Sub-Micron Positioning Accuracy, Campbell RAA, Eifert RW, Turner GC (2014) Openstage: A Low-Cost Motorized Microscope Stage with Sub-Micron Positioning Accuracy. PLOS ONE 9(2): e88977. [2] Step-by-step guide to building an inexpensive 3D printed motorized positioning stage for automated high-content screening microscopy, Dominik Schneidereit, Larissa Kraus, Jochen C. Meier, Oliver Friedrich, Daniel F. Gilbert, Biosensors and Bioelectronics, 92:472-481, (2017)	Students can focus on a subset of the project depending on their interests and available time: 1. Literature review: Review current literature that is relevant to the design of the hardware/software components. 2. Choose microscope platform: Prospective students can choose to motorize our manual microscopes. 3. Design: Design hardware components: Design a custom stage for the microscope of choice. This will encompass both 3d mechanical design and the design of the electronics (Arduino, stepper motors, power supply etc.). 4. Prototyping: Using the university fabrication facility build a working prototype. 5. Software development: Create a simple application to control the available hardware.	Basic programming skills in Python, C# or C/C++.
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Motion Blur Removal Using SfM Geometry	Motion blur is an inherent limitation of video captured under motion, and it is conventionally treated as a blind image restoration problem in which both the sharp image and the unknown blur kernel must be recovered simultaneously. This project takes a different route by exploiting the fact that a Structure from Motion pipeline already recovers precisely the quantities that generate the blur: the camera trajectory, the intrinsic parameters, and after dense reconstruction the scene depth. Since a blurred frame can be modelled as the integral of the sharp image over the exposure interval, warped by the time-varying camera pose, these estimates allow the spatially varying blur kernel to be synthesised directly rather than guessed. The primary objective is to implement a pipeline that derives per-pixel blur kernels from SfM output and applies non-blind deconvolution, thereby converting a severely ill-posed blind problem into a geometrically constrained one. The project begins with a thorough exploration of the topic and a survey of the current state of the art, covering both classical geometry-driven deblurring and recent approaches that jointly optimise scene representation and camera motion. Students are then expected to select representative methods, reproduce their results on real recordings, and evaluate them critically, identifying the assumptions on which they depend and the conditions	Review classical and recent motion deblurring approaches, with particular emphasis on geometry-based methods using camera motion and scene depth. Implement a pipeline that estimates spatially varying motion blur kernels from SfM-derived camera poses, camera intrinsics, and reconstructed scene geometry. Apply non-blind deconvolution using the estimated blur kernels and compare the results with representative blind and learning-based deblurring methods. Evaluate the approach on synthetic and real video sequences with different camera motions, scene depths, exposure times, and levels of motion blur. Analyze the sensitivity of the method to errors in camera pose estimation, depth reconstruction, calibration, and other assumptions of the geometric blur model.	Python, Basics of computer vision
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Surface Reconstruction from 3D models after Gaussian Splatting	While 3D Gaussian Splatting (3DGS) has recently revolutionized novel view synthesis with its exceptional rendering speed and visual quality, its underlying scene representation relies on unstructured volumetric ellipsoids rather than explicit geometric surfaces. This project addresses the critical challenge of deriving accurate, continuous 3D surfacemeshes from trained 3DGS models. The primary objective is to investigate and implement state-of-the-art surface extraction techniques, bridging the gap between high-fidelity volumetric radiance fields and traditional polygon-based 3D geometry, which remains essential for physical simulations, collision detection, and standard rendering engines. To rigorously evaluate the effectiveness of the surface reconstruction methods, the research will utilize video data from two contrasting real-world scenarios. The first dataset will feature complex indoor environments captured via handheld mobile devices, testing the algorithms against variable lighting, occlusions, and detailed close-range geometries. The second scenario will rely on large-scale outdoor footage recorded by vehicle-mounted cameras to assess the robustness, scalability, and mesh completeness along continuous, dynamic trajectories. By applying the surface extraction pipelines to these diverse environments, the project will benchmark the geometric precision and overall quality of	Review state-of-the-art methods for extracting explicit surfaces and polygonal meshes from trained 3D Gaussian Splatting representations. Implement and compare selected surface reconstruction techniques using 3DGS models generated from real video sequences. Evaluate the reconstructed surfaces on handheld indoor recordings and large-scale vehicle-mounted outdoor recordings. Analyze mesh quality in terms of geometric accuracy, completeness, surface consistency, artifacts, and robustness to challenging viewing conditions. Compare the computational cost and practical applicability of the investigated methods for applications requiring explicit geometry, such as simulation, navigation, or collision detection.	Python, Basics of 3D computer vision
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Affine Transformations for SfM/SLAM	Traditional Structure from Motion (SfM) and Simultaneous Localization and Mapping (SLAM) systems typically output sparse 3D point clouds that lack explicit information about the underlying surface geometry. This research project focuses on exploiting local affine transformations between image pairs to extract significantly richer geometric data. By mathematically analyzing how local image patches deform between views—based on known or estimated affine transformations—it is possible to compute not only the precise 3D coordinates of a point but also its corresponding surface normal. This novel approach directly yields the orientation of the observed surfaces, seamlessly bridging the gap between sparse point extraction and dense surface reconstruction. As an integral part of an ongoing, specialized research initiative, this project offers students the opportunity to dive deep into projective geometry and advanced computer vision algorithms. The primary objective is to implement, refine, and test these affine-based mathematical models to reliably estimate normal vectors within standard SfM/SLAM frameworks. Students will be tasked with validating the methodology using diverse image pairs, analyzing the accuracy of the computed surface normals, and exploring how this enriched spatial data can improve subsequent tasks such as dense	Review the theoretical background of local affine correspondences, projective geometry, and their application in SfM and SLAM. Implement methods for estimating 3D points and local surface normals from affine correspondences between image pairs. Integrate the proposed affine-based geometric estimation into a representative SfM or SLAM pipeline. Evaluate the accuracy and robustness of the estimated surface normals under different viewpoints, image noise, matching errors, and scene geometries. Investigate how the additional surface orientation information can improve downstream tasks such as surface reconstruction, meshing, or camera tracking.	Python, Basic 3D computer vision
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GPU exploitation for real-time 3D reconstruction and mapping	Achieving real-time 3D reconstruction and mapping remains a significant computational challenge, largely due to the massive volume of visual data and the complex optimization algorithms required. This project aims to investigate, implement, and evaluate advanced GPU exploitation strategies to dramatically accelerate these computer vision pipelines. By leveraging modern GPU architectures, parallel processing paradigms (such as CUDA), and optimized memory management, the research will focus on overcoming traditional bottlenecks to reduce processing times without compromising spatial accuracy or visual fidelity. The scope of the project is technology-agnostic, allowing for the exploration of various 3D reconstruction methodologies. This could range from identifying bottlenecks and extending established photogrammetry pipelines—such as accelerating feature extraction, matching, or bundle adjustment in COLMAP—to optimizing newer neural, volumetric, or SLAM-based approaches. The primary task is to apply targeted hardware acceleration techniques and benchmark the resulting performance against standard implementations, ultimately demonstrating a clear pathway toward robust, real-time mapping solutions suitable for autonomous navigation, robotics, or augmented reality.	Review GPU acceleration techniques relevant to 3D reconstruction, mapping, SLAM, and photogrammetry pipelines. Select a representative reconstruction pipeline and identify its main computational and memory bottlenecks. Implement GPU-based acceleration for selected components, such as feature extraction, feature matching, optimization, depth estimation, or map updates. Benchmark the accelerated implementation against the original baseline in terms of runtime, throughput, GPU utilization, memory usage, and reconstruction accuracy. Investigate the feasibility of real-time or near-real-time operation and identify further opportunities for hardware-aware optimization.	Python
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RTAB-Map-Based Real-Time 3D Mapping on a Drone Using Jetson NX	The aim of this project is to develop an RTAB-Map-based 3D SLAM and mapping pipeline for an NVIDIA Jetson NX embedded platform with 8 GB of memory installed on a drone. The current system uses Ubuntu 18.04, therefore the proposed solution must be compatible with the existing software and hardware environment.	Install and configure an RTAB-Map-based SLAM pipeline and establish a working baseline on the Jetson NX platform. Profile the computational and memory requirements of the pipeline. Evaluate mapping and localization accuracy, runtime performance, and memory usage. Test the solution in a drone or drone-like motion environment.	Python, C++
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Packaging SAMannot as a Python Package and Improving Its Usability	SAMannot is an open-source video annotation software built on Meta's Segment Anything Model 2 (SAM2). Its goal is to enable the creation of high-quality segmentation annotations in a local environment, even when only limited computational resources are available. At present, SAMannot can be installed and run by following the documentation of the GitHub repository, provided that the user has basic technical knowledge. However, supporting broader adoption, especially among researchers without a computer science background, requires simplifying the installation and startup process. One of the main goals of this thesis is therefore to turn SAMannot into a standard Python package that can be installed using a conventional pip install command and launched using a simple command-line entry point. The other main part of the work is to review smaller functional and user-experience improvements identified during the practical use of SAMannot, design appropriate solutions, and implement a jointly selected subset of these enhancements.	Analyze the current installation process and dependencies of SAMannot, with particular attention to the handling of SAM2, PyTorch, model checkpoints, and hardware-dependent components. Convert the codebase into a standard Python package that can, where possible, be installed using a command similar to pip install samannot and launched through a simple command-line entry point after installation. Investigate and document technical challenges and limitations arising during packaging, including the handling of large model files, platform- and CUDA-specific dependencies, and external components. Review user feedback and development needs, then implement and/or integrate a selected set of usability or functional improvements into the SAMannot application. Test the resulting solution and prepare detailed developer documentation that, in addition to describing the SAMannot-specific solution, can also serve as a general guide for packaging similar Python-based research software for straightforward installation and use.	Python
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Quantization and Memory Optimization of 3D SLAM and Reconstruction Transformer Models	The high computational and memory requirements of vision transformer-based 3D SLAM and reconstruction models significantly limit their use on embedded and mobile platforms. The aim of this project is to reduce their memory footprint and computational requirements using quantization and other model optimization techniques (KV-cache compression, adaptive state updates), while minimizing the degradation of reconstruction and localization accuracy. The project should investigate different numerical representations and quantization strategies, and evaluate their impact on memory usage, runtime, and accuracy. If necessary, additional optimization approaches may also be explored, such as using different numerical precision levels for individual model components or reducing the memory requirements of intermediate representations. The longer-term goal is to make the selected models executable within resource constraints suitable for future deployment on go-kart, mobile, and drone platforms.	Review state-of-the-art transformer-based 3D SLAM and reconstruction models and select one or more baseline models. Profile the memory usage, computational requirements, and runtime characteristics of the selected models. Study, analyze, and compare quantization and memory optimization methods. Implement a selected optimization method. Investigate the sensitivity of individual model components to quantization. Evaluate the trade-off between accuracy, runtime, and memory usage. Assess the feasibility of future deployment on go-kart, mobile, and drone platforms.	Python, Basics of computer vision
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Efficient Incremental and Local Updating of 3D Gaussian Splat Models Based on Environmental Changes	Given a 3D Gaussian Splat (GS) model of an environment reconstructed from RGB video, parts of the environment may have changed since the original recording. The aim of this project is to develop an efficient incremental update method for the GS model so that local environmental changes do not require rebuilding the complete 3D model. The input describing the change is provided through manual annotations on the 2D frames in which the change is visible. Based on the camera poses associated with the annotated frames, the affected local region of the GS model can be identified. Starting from the camera poses that observe the change and can be treated as key viewpoints, only the affected local subgraph and the corresponding Gaussian splats should be updated. The project should investigate how timestamps and the Markov property of temporal environmental changes can be exploited to identify the part of the model that requires updating and to reduce computational cost. Another important aspect is the detection and filtering of moving objects. Such objects should not be incorporated into the environment model as persistent changes, as this could degrade the quality of the GS representation and cause unnecessary model updates and additional latency. One potential application of the method is a navigation system based on a continuously maintained 3D environmental model, for example to support indoor navigation for visually impaired users. The primary development platform for the prototype is an NVIDIA RTX 5090 GPU. In the	Review methods suitable for incremental and local updating of 3D Gaussian Splat models. Identify the local subgraph and Gaussian splats associated with camera poses affected by the environmental change. Develop an update procedure that modifies only the affected region without rebuilding the complete 3D model. Investigate update strategies based on timestamps and the Markov property of temporal environmental changes. Detect and filter moving objects to avoid unnecessary model updates. Evaluate the quality, latency, computational requirements, and memory usage of the local update method.	Python, Basics of computer vision
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Detection, Tracking, and Localization of 3D Environmental Changes from RGB(D) Video	A 3D model of an environment can be reconstructed from RGB or RGB-D video, for example from footage captured using a mobile phone. The aim of this project is to develop a primarily detection-by-tracking-based change detection method that automatically detects, localizes in 3D, and tracks relevant environmental changes with respect to a previously reconstructed state of the environment. The method should handle changes primarily in a class-agnostic manner. Unrecognized objects or regions do not necessarily need to be assigned semantic categories; however, they should still be taken into account for applications such as obstacle detection or collision avoidance. The system may be complemented by a small closed-set model containing a limited number of known object classes, for example by lifting 2D detections or segmentation results into 3D. Additional semantic information may also be incorporated periodically. Changes may be detected by comparing the current camera image with a reference view generated from the previous 3D model at the corresponding camera pose, or directly within the 3D representation. The project should investigate the combination of 2D and 3D information, as well as the association of camera poses and observations between previous and current recordings. The method should track spatially coherent objects or regions in 3D and adapt over time to their appearance, disappearance, movement, merging, and splitting. Particular emphasis should be placed on handling multiple simultaneous changes,	Review the relevant literature and select an appropriate underlying 3D representation and reference-state representation. Investigate 2D and/or 3D methods suitable for automatically detecting changes between a previously reconstructed 3D environmental model and current camera observations. Implement a prototype of a detection-by-tracking-based 3D change detection method capable of tracking objects and regions that appear, disappear, move, merge, or split over time. Investigate the association of camera poses, frames, and 3D observations between previous and current recordings. Investigate and integrate closed-set and ignored-set object handling, including the use of periodically incorporated 2D semantic or segmentation information. Investigate the handling of multiple simultaneous environmental changes and their localization in 3D. Determine relevant camera poses, including poses providing good observability, for the detected changes. Evaluate the robustness of the method under varying object sizes, distances, and viewing angles, as well as localization, reconstruction, and image noise. Experimentally evaluate the proposed solution in terms of detection and tracking performance, 3D localization accuracy, computational time,	Python, Basics of computer vision
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Quantitative and AI-Based Analysis of Surgical Motion Using Optical Motion Capture	The project aims to develop a reproducible data-processing and analysis pipeline for surgical movement data recorded with a Qualisys optical motion capture system. Measurements will initially be performed in a laboratory environment using surgical or anatomical models and may later be extended to measurements conducted at the Semmelweis University NOIKK. The analysis will focus on the quantitative characterization of surgical movements, the identification of movement phases and patterns, and the exploration of features related to movement efficiency, consistency, coordination, and technical execution.	Participate in the development and testing of the motion capture protocol and marker configuration. Process Qualisys trajectory data, including synchronization, filtering, gap filling, quality control, and data structuring. Extract and visualize relevant movement features, such as trajectory length, velocity, acceleration, smoothness, movement variability, and inter-segment coordination. Develop methods for identifying and comparing surgical movement phases and recurring movement patterns. Implement and evaluate baseline statistical or machine-learning models for movement classification, segmentation, or trial comparison. Package the developed methods into a documented and reproducible analysis pipeline.	Python, data processing, time-series analysis, basic statistics, and visualization . Advantage: signal processing, machine learning, biomechanics, or experience with motion capture data.
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Spatiotemporal features of human single neuron waveforms revealed by intraoperative high-density in vivo recordings	High-density laminar silicon probes have been widely used in rodent electrophysiology but were virtually absent from human research until recently. Clinical research devices have so far been able to detect single-unit activity (SUA) with a poor spatial resolution (due to large inter-contact distances) or they have been limited to recording only the low-frequency component of the extracellular neural activity (local field potentials). We pioneered a rare opportunity to test state-of-the-art silicon probes (namely the custom-designed, backside-thickened Neuropixels 1.0-S probes) in the operation room setting during resective surgeries in the cases of tumors or epilepsy or the implantation of a deep brain stimulator (DBS) in patients with Parkinson's disease. These probes feature hundreds of closely packed active contact sites enabling for multi-channel oversampling of extracellular SUAs. Spatiotemporally resolved morpho-electric properties of single units allow us for sophisticated clustering of neural cell types. Among several spatiotemporal features of cortical neurons, in this study we first focus on the so called the backpropagating action potential (bAP). Intracellular spikes can propagate backward along the somatodendritic axis. This phenomenon can also be detected extracellularly on spike-triggered averages (STAs) of the corresponding SUAs after spike sorting. These bAPs have been observed in rodents (using standard Neuropixels 1.0 probes) in vivo with distinct spatiotemporal patterns across brain regions, putative cell types, and morphological	- Study of the scientific literature, finding and reading research methods and publications - Familiarization with multichannel electrode recording techniques, experimental protocol and instrumentation - Visiting and assisting in vitro and in vivo experiments - Participation in group meetings, lab meetings, journal clubs - Analysing and interpreting neural data, developing a multi-step data analysis pipelines, following and implementing data analysis toolboxes (GitHub) - Visualization of scientific results obtained, statistical interpretation, presentation of results	- Programming skills at least in one of the following languages: MATLAB, C++, Python (preferred, but it can also be learned on the fly) - Advantage: Interest or Previous Experience in Machine Learning, Statistics, Modeling, Data Science - Have a keen interest in experimental neurobiology
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From Full-Body Instrumentation to Minimal Wearables: Multimodal Knowledge Distillation for Parkinsonian Gait Assessment	Wearable sensors enable objective assessment of gait impairments and freezing of gait in Parkinson's disease, but systems using many sensors are difficult to apply in everyday clinical or home environments. The aim of this project is to develop an artificial intelligence method that transfers information learned from a comprehensive multimodal sensor system to a practically usable configuration containing only one to three inertial measurement units. Using an open-access dataset, a multimodal teacher model will be trained on synchronized data from 13 IMUs, plantar-pressure insoles and instrumented gait measurements. Its knowledge will then be transferred to smaller student models using knowledge distillation. The models will be evaluated for estimating clinically relevant gait characteristics, disease severity or freezing-of-gait-related outcomes. Particular attention will be paid to participant-independent validation, uncertainty estimation and model explainability. The project requires no new measurements and is based entirely on secondary analysis of an existing dataset.	Review the relevant literature on wearable gait analysis, Parkinson's disease and multimodal knowledge distillation. Become familiar with the WearGait-PD dataset and develop a preprocessing pipeline for its synchronized sensor data. Design and implement baseline, multimodal teacher and reduced-sensor student models. Evaluate different sensor configurations using strictly participant-independent validation and appropriate statistical methods. Interpret the models using explainable-AI and uncertainty-estimation techniques, and document the results.	Basic knowledge of Python programming, machine learning, statistics and digital signal processing.
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Performance and Convergence Analysis of Sparse Linear Solvers on Parallel Architectures	Solving large-scale sparse linear systems $Ax = b$ is a fundamental computational bottleneck in scientific computing, engineering simulations, and data science. While modern parallel architectures (multi-core CPUs and GPUs) offer massive theoretical compute throughput, sparse matrix operations are heavily memory-bandwidth bound. This project investigates the trade-offs between solver runtime, memory access patterns, and mathematical convergence behavior. The student will explore both direct and iterative solvers (e.g., Krylov subspace methods such as CG and GMRES, combined with various preconditioning techniques) using modern parallel sparse linear algebra frameworks. The ultimate goal is to benchmark, profile, and analyze how problem conditioning, sparsity structure, and hardware-level parallelism influence overall time-to-solution.	◦Review the literature on parallel sparse matrix storage formats (CSR, ELLPACK) and iterative solvers (CG, GMRES, BiCGSTAB) with preconditioning. ◦Select and set up a representative benchmark suite of sparse matrices from real-world scientific applications (e.g., SuiteSparse Matrix Collection). ◦Implement or integrate solver pipelines using standard high-performance libraries (e.g., PETSc, Ginkgo, cuSPARSE, or Eigen). ◦Perform detailed performance and convergence benchmarks across multi-core CPU and GPU targets, profiling bottleneck factors such as memory bandwidth utilization. ◦Analyze the measurement results, document the performance trade-offs, and summarize the findings in the final report.	Foundations in numerical analysis and C++/Python
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Adapting Neural Networks to Evolving Labels in Real-World Applications	Machine learning models are typically trained on fixed datasets with stable/constant labels. However, in real-world scenarios, the meaning of labels can change over time — for instance, the sentiment associated with certain words or expressions may shift from positive to negative. Such dynamic labeling challenges the conventional assumption of static datasets and necessitates mechanisms for neural networks to adapt. This research aims to explore how neural architectures can be modified or "rewired" to accommodate evolving labels without retraining from scratch. The student will investigate methods for continual learning, dynamic label adaptation, and mechanisms that allow models to reinterpret previously learned samples under new label semantics. Understanding these processes is critical for applications such as sentiment analysis, natural language processing, and adaptive decision-making systems.	Review literature on continual learning, concept drift, and dynamic labeling. Develop methods to adapt neural networks to changing labels in previously trained datasets. Implement and test algorithms for rewiring or fine-tuning models under evolving label conditions. Evaluate the performance of proposed methods on benchmark datasets with simulated or real label shifts. Analyze the trade-offs between adaptability, stability, and computational efficiency.	
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Movement and Gesture Analysis for Psychiatric Illnesses	This research topic, in collaboration with the Psychological Institute of SOTE, focuses on developing quantitative methods to analyze movement patterns in individuals with psychiatric illnesses. Subtle differences in gestures, posture, and motion sequences can reflect underlying mental health conditions, making movement analysis a valuable diagnostic and monitoring tool. The project aims to design computational approaches for extracting characteristic metrics from video recordings, such as velocity, smoothness, and coordination of movements. These metrics will then be used to distinguish between healthy individuals and patients with psychiatric disorders. The work combines computer vision, signal processing, and machine learning techniques, bridging the gap between computational sciences and clinical applications. The outcomes are expected to support objective and reproducible assessments of psychiatric conditions, offering clinicians additional insights beyond traditional observation-based evaluations.	Develop algorithms to extract movement features from video recordings. Implement quantitative metrics (e.g., velocity, smoothness, coordination) for gesture and motion analysis. Train and evaluate machine learning models for classifying healthy and psychiatric patient groups. Validate the extracted metrics and classification performance using real patient datasets. Collaborate with psychologists to interpret results in a clinical context.	
Dynamic properties of generative networks	Generative networks have recently undergone significant development and are now able to produce text and images with a high degree of fidelity at large scale. The aim of this topic is to investigate the dynamic properties of these models when considered as an autonomous system. In other words, to what extent do they generate new content starting from a given prompt or converge to constant, periodic, or even chaotic dynamics after a certain time?	- learn about the most commonly used generative models - create an environment in which generative models of different complexity can be run - examine the dynamic properties of these models for different inputs - compare the dynamic properties of models of different complexity - draw conclusions from the measurements.	

Development Oscillator based neural networks	Oscillatory networks are a fascinating aspect of computational science, as they are ubiquitous in nature and offer a promising avenue for achieving more robust and energy-efficient continuous-time computational models. While current neural networks have achieved remarkable success in various applications, they often come with a significant energy consumption drawback. This project proposal aims to delve into the world of oscillatory networks, harness their potential, and develop a Python-based simulator to evaluate basic oscillator networks on traditional machine learning tasks. This project seeks to unlock the computational potential of oscillatory networks and their applications in the context of energy-efficient and robust machine learning. By developing a versatile simulator and conducting thorough evaluations, we aim to contribute valuable insights to the field of continuous-time computation and offer potential solutions for energy-intensive machine learning challenges.	Oscillator Network Development: We will design and implement a versatile oscillator network framework in Python. This framework will allow us to experiment with different types of oscillatory units and topologies, enabling a comprehensive exploration of their computational capabilities. Energy Efficiency Evaluation: One of the primary goals is to assess the energy efficiency of oscillator networks compared to conventional neural networks. We will conduct extensive experiments to quantify the energy savings achieved by using oscillatory networks for various computational tasks. Robustness Analysis: We will investigate the robustness of oscillatory networks by subjecting them to noisy and dynamic environments. This analysis will help us understand the resilience of oscillatory models in real-world scenarios.	
Investigation of adversarial samples in machine learning	The aim of this task to investigate how adversarial attacks can be generated, detected and recovered in machine learning in various image processing tasks such as classification, detection and segmentation.	literature review in the field of adversarial attacks and NERFs Development and evaluation of different attack methodologies on generalized NERF models	Programming, mathematical skills and basic knowledge of neural networks

Evaluating World-Model Consistency in Large Language Models Through Rule-Based Games	Large Language Models (LLMs) demonstrate an ability to follow structured rules and play games such as chess and Go. However, they sometimes exhibit inconsistencies in their world model, leading to rule violations or logically inconsistent moves. This research aims to systematically assess LLMs' ability to maintain internal consistency when playing rule-based games. By analyzing their performance across different types of structured games, we can quantify their tendency to adhere to a fixed rule set and identify factors influencing their world-model consistency. Insights from this study could improve LLM reasoning capabilities, especially in structured and logic-dependent applications.	- Select a range of structured, rule-based games (e.g., chess, Go, tic-tac-toe, Sudoku) and design a benchmarking framework to measure LLM adherence to game rules over multiple iterations. - Identify and categorize instances where LLMs fail to follow game rules, including hallucinated moves, logical contradictions, or gradual degradation of adherence over extended play. - Investigate how different prompting strategies (e.g., explicit rule reinforcement, step-by-step reasoning) and context window lengths affect LLM consistency in maintaining game rules. - Evaluate multiple LLMs (e.g., GPT-4, Claude, Gemini, open-source models) to determine whether rule-following inconsistencies are model-dependent and how different training paradigms influence performance. - Explore methods to enhance LLMs' rule-following behavior, such as fine-tuning on structured logic-based tasks or integrating external validation mechanisms to correct inconsistencies in real-time.	
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Self-motion and orientation estimation for aircraft	The goal of the project is to augment the capabilities of the widespread GPS/IMU-based self-motion estimation algorithms with information available from onboard camera images. The first part is to do a comprehensive literature review on the state-of-the-art and then develop new algorithms for the task. Also, it is important to run tests to determine the statistical properties of these algorithms. The test is run either on videos rendered by the simulator or also on flight videos. Preliminary algorithms, scientific papers, the simulator, and flight videos are available for the job. Unmanned Aerial Vehicles, UAV, sensor fusion, collision avoidance, video and image processing	Conduct a comprehensive literature review on the state-of-the-art GPS/IMU-based self-motion estimation algorithms and techniques that integrate onboard camera images. Develop new algorithms that augment GPS/IMU-based self-motion estimation with information extracted from onboard camera images. Assess the statistical properties of the newly developed algorithms to ensure reliability and accuracy. Execute tests on the new algorithms using videos rendered by the available simulator, as well as real-world flight videos to validate performance. Compile findings, including test results and algorithmic approaches, into scientific papers for dissemination and further study.	C++, Matlab, OpenCV, OpenGL
Camera based collision avoidance methods for unmanned aerial vehicles	The widespread use of unmanned aerial vehicles (UAV) increases the risk of accidents, therefore new procedures must be developed to avoid dangerous approaches and collisions. Due to the size of small UAVs only passive image processing systems can be used. However, high-resolution cameras are required to detect dangerous aircraft from a large distance. The goal of the topic is to explore the opportunities of deep open set recognition in UAV sense-and-avoid. The work can be done individually or in a small team as well.	The tasks are 1) literature review 2) implementation of SAA algorithms 3) data exploration and annotation 4) algorithm testing	Programming (at least one of the following: C, C++, MATLAB, Python, Java), Basics of Machine Learning, Basics of Computer Vision

Cave mapping with drones	The goal is to build a system based on drones and their associated sensors, which will be suitable for mapping caves. During the design, our primary considerations were that the system should be affordable and have the proper dimensions and flight time. The basis of the system will be a small drone, which will primarily be equipped with several cameras (EO, IR) and LiDAR. Today, several similar projects are underway around the world, such as Caveatron or Zebedee. There are non-laser-based approaches, but significantly fewer of them, and not many have achieved significant results so far. The goal is to develop a more efficient method for exploring caves. The advantage of drones is that they are not only fast but also small in size. Thanks to this, they can fit into many places where it would not be possible to get in otherwise, and due to their design, they can also quickly move in a vertical direction.	Design a drone-based system with associated sensors tailored for cave mapping, ensuring it is affordable, properly dimensioned, and has sufficient flight time. Equip the small drone at the core of the system with a range of cameras (EO, IR) and LiDAR technology to capture comprehensive data within caves. Conduct a comparative analysis of existing projects and methods, such as Caveatron and Zebedee, and assess the efficacy of non-laser-based approaches in cave mapping. Develop a more efficient methodology for cave exploration, leveraging the drones' speed and small size to access and map areas otherwise difficult to reach. Validate the system's capabilities through field testing, particularly focusing on its ability to navigate vertically and fit into tight spaces within caves.	Programming (at least one of the following: C, C++, MATLAB, Python, Java), Basics of Computer Vision, Basics in electronics and hardware integration
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Application of deep learning methods for improvement of self-organizing maps in multidimensional time series representation	Self-Organizing Maps (SOM, Kohonen Network, etc.) are capable of representing the input space of the training set by a map. However, the best initialization of the network and the dimensional reduction of the input data have to be investigated. The hypothesis is that by applying deep learning methods such as augmentation of SOM, or Time adaptive SOM (TASOM) the representation of large scale and multidimensional time-series data can be improved. The objective is to determine an efficient structure and learning methods that are capable of representing such time series and can perform classification or clustering with high precision.	Investigate optimal initialization methods for Self-Organizing Maps (SOM, Kohonen Network) to best represent the input space of the training set. Explore techniques for dimensional reduction of the input data to enhance the performance of the SOM. Evaluate the potential improvements in representing large-scale and multidimensional time-series data by applying deep learning methods like Augmentation of SOM or Time Adaptive SOM (TASOM). Determine an efficient network structure that is capable of accurately representing the time-series data in question. Develop and test learning methods aimed at achieving high-precision classification or clustering based on the optimized SOM structure.	Programming skills (C++ or Python), Basics of Machine Learning
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Camera based collision avoidance methods for unmanned aerial vehicles, simulator environment development	The task is to develop a simulator environment to support the algorithmic and hardware development, based on an existing simulator system. The improvement of the parts of the current system is necessary, like the rendering engine (Ogre vs FlightGear, test with new versions), testing and communication with image processing hardwares (GPU, FPGA). A very important part is also to write a comprehensive documentation on the setup. Unmanned Aerial Vehicles, UAV, FPGA, GPU, collision avoidance, video and image processing	Adapt and expand an existing simulator environment to facilitate both algorithmic and hardware development for the project. Upgrade components of the current system, including evaluating and possibly updating the rendering engine by comparing Ogre vs FlightGear and testing with newer versions. Implement and test communication interfaces between the simulator and image processing hardware, such as GPUs and FPGAs. Write comprehensive documentation detailing the simulator setup, including hardware and software configurations. Conduct thorough testing to validate the efficacy and compatibility of the enhanced simulator environment with the intended algorithmic and hardware developments.	C++, Matlab, OpenGL
Face recognition and tracking on UAV swarm	The implementation of face recognition and tracking technology on UAV swarms is a promising development direction that has the potential to enhance security, improve surveillance, and aid in search and rescue operations. The ability to identify and monitor individuals from the air is a powerful tool that can assist in creating a safer environment in a large work area.	- Review the relevant literature - Design and install the measurement system for the UAV swarm - Record data to develop the swarm control and face-tracking algorithms - Assess the results, preferably comparing them to the state-of-the-art - Write a report summarising your work	Programming skills. Knowledge of Linux.

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Testing the functions of neural microsystems	It is known from experiments that changes in body temperature affect electrical signals and metabolic processes in the brain. Microsystems implantable into neural tissue are manufactured for exploring these connections which microsystems are even suitable for freely behaving in vivo experiments. The applicant has to observe the functioning of the integrated thermal and electrophysiological sensors in experimental conditions, and has to calibrate them in vitro. Beyond designing and assembling the measuring system the applicant has to fulfil documented functional tests of the implantable microtools. This topic is suitable for a further desired TDK work.	- learn about the biological basis of thermal neuromodulation - get to know the microdevices in question: MEMS fabrication technology, electrode components, functions - get to know the measurement methods suitable for testing various integrated functions - design and assemble functional test measurements (+ control and evaluation scripts) - regularly documents his/her work as agreed with the supervisor(s)	basic mathematical, physical and computer skills (measurement technology, statistics)
Implementing deep learning neural networks on FPGAs	Design methodology of image processing systems has changed fundamentally in the recent years. The previous methods based on heuristics are replaced by deep learning neural networks trained for a specific task. Using the trained network during inference requires high computing power. In low-power embedded systems application specific accelerators implemented on FPGA are required. Different recognition tasks might require different network structure therefore adaptability of the network description is very important. The student should be acquainted with the frameworks for implementation of deep learning neural networks on FPGA and solve a specific recognition task.	Get familiar with the Xilinx FPGA architecture. Get familiar with the Xilinx FPGA development systems (Vitis, Vitis HLS, Vivado). Review the literature on Neural Networks and its implementation on FPGA. Develop and test a C/C++ implementation of a Neural Network. Implement the developed algorithm on FPGA. Test the operation of the implemented system using simulation. Determine the main operating parameters of the system, speed, implementation area, and power dissipation.	Basic knowledge in digital circuits, FPGA architectures, C/C++, Python

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Accelerating fluid dynamics computations on FPGA	The task of the student is to accelerate the solution of partial differential equations describing fluid flow in 2 or 3 dimensions and for compressible or incompressible fluids. Design and implement the optimal architecture, arithmetic unit and memory interface for the different equations on FPGAs. Examine the computing accuracy required for the solution and evaluate the available computing performance of the architecture.	Get familiar with the AMD FPGA architecture. Get familiar with the AMD FPGA development systems (Vitis, Vitis HLS, Vivado). Review the literature on algorithms solving fluid dynamics problems. Develop and test one selected algorithm in C/C++. Implement the proposed algorithm on FPGA. Test the operation of the implemented system using simulation. Determine the main operating parameters of the system, speed, implementation area, and power dissipation.	Basic knowledge in digital circuits, FPGA architectures, C/C++, Python
Acceleration of compute intensive applications on FPGA	Acceleration of compute-intensive application on FPGA consulted with co/external supervisor. Basically, interesting algorithms provide large potential parallelism and contain relatively short repeating series of instructions. (Eg. solution of partial differential equations such as electromagnetic simulations, reaction path search, gene/protein sequence alignment, classification of neural spikes, and image processing.) The task involves searching and processing the required literature to solve the problem, implementing the software algorithm, and designing the accelerator hardware and its testing as well.	Get familiar with the AMD FPGA architecture. Get familiar with the AMD FPGA development systems (Vitis, Vitis HLS, Vivado). Review the literature on the selected topic. Develop and test the C/C++ implementation of the selected algorithm. Implement the proposed algorithm on FPGA. Test the operation of the implemented system using simulation. Determine the main operating parameters of the system, speed, implementation area, and power dissipation.	Basic knowledge in digital circuits, FPGA architectures, C/C++, Python

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Development of 10Gb Ethernet interface and TCP/IP packet processing circuit for FPGA	Acceleration of complex algorithms working on large datasets on FPGA (such as: solution of Partial Differential Equations, medical image reconstruction, processing large biological databases) might be influenced by the speed of the communication channel between the host PC and the FPGA board. The bandwidth of the standard Gigabit Ethernet interface is not high enough. The hardened PCI-Express interface on the FPGAs can provide high bandwidth but its usage requires kernel level driver development in most cases. As an alternative 10Gbit Ethernet interface can be used, which makes it possible for the host computer to communicate via standard TCP sockets with the accelerator on the FPGA. Another advantage is that the 10Gbit Ethernet interface also allows the development of diverse network topologies between multiple hosts and FPGA cards. Processing, classification and filtering of the incoming TCP packets must be executed by a dedicated hardware block, due to the limited computing power of the microprocessors integrated into FPGAs. The task of student is to get acquainted with Ethernet, IP and TCP standards and the operation of the Xilinx 10G Ethernet interface module. After mastering the theoretical basics, design a circuit capable of handling TCP connection(s) and packets, and integrate it into an embedded system with a Microblaze or ARM Cortex-A9/A53 processor.	Get familiar with the AMD FPGA architecture. Get familiar with the AMD FPGA development systems (Vitis, Vitis HLS, Vivado). Review the literature on the IP, UDP, and TCP protocols. Develop and test the C/C++ implementation of the UDP or TCP packet handling system. Implement the proposed algorithm on FPGA. Test the operation of the implemented system using simulation. Determine the main operating parameters of the system, speed, implementation area, and power dissipation.	Basic knowledge in digital circuits, FPGA architectures, C/C++, Python, TCP/IP, VHDL
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Development of an embedded image processor architecture on FPGAs	The widespread use of unmanned aerial vehicles (UAV) increases the risk of accidents, therefore new procedures must be developed to avoid dangerous approaches and collisions. Due to the size of small UAVs only passive image processing systems can be used. However, high-resolution cameras are required to detect dangerous aircrafts from a large distance. High computing performance is required to process real-time image streams arriving from the cameras, which can only be achieved quickly and efficiently by using application specific image processing architectures. One possible way is to use FPGA, which allows high computational power with relatively low power consumption and reasonable development times. The task is to develop an FPGA system which runs the previously developed and tested SAA algorithm.	Get familiar with the AMD FPGA architecture. Get familiar with the AMD FPGA development systems (Vitis, Vitis HLS, Vivado). Review the literature on the visual detection of small unmanned aerial vehicles (UAV). Develop and test the C/C++ implementation of the selected algorithm. Implement the proposed algorithm on FPGA. Test the operation of the implemented system using simulation. Determine the main operating parameters of the system, speed, implementation area, and power dissipation.	Digital circuits, FPGA, C/C++/Python, OpenCV, Matlab
Complex dynamics and basic computations in cortical networks	Our aim is to reveal the basic computations carried out by cortical neural networks. Simulations of networks of both biophysically detailed and simplified model neurons are used to investigate emergent network dynamics, efficient coding, and learning. The task is to develop new models of hippocampal neurons and synapses, to perform simulations of the network, to analyze oscillations, transient dynamics, and coding, and to compare the results to experimental data. The work is carried out using special simulation tools as well as internally developed software.	- Review the literature on hippocampal network dynamics, plasticity, and coding - Develop new models of hippocampal neurons and synapses - Perform simulations of the network - Analyze oscillations, transient dynamics, and coding - Compare the results to experimental data.	The most important requirement is a strong interest in neuroscience. Some programming experience and working knowledge of English are also needed.

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Using agentic artificial intelligence to accelerate research in computational neuroscience	A variety of artificial intelligence (AI) methods are becoming standard tools in scientific research. An emerging trend involves the application of agentic AI systems, which promise to handle some or even all parts of the scientific process (including the identification of open problems, hypothesis generation, experimental design, data analysis and publication) in a mostly autonomous manner involving minimal human intervention. Simulation-based science also allows the actual experiments to be carried out by AI agents, which are capable of generating and executing the code that builds and simulates the model. The aim of this project is to test the applicability of this approach to computational neuroscience by using state-of-the-art agentic AI systems to design, execute and evaluate simulation experiments involving detailed models of single neurons or simplified models of cortical networks.	- become familiar with the general methodology of using agentic AI systems - explore the most popular autonomous AI scientists, and choose one for the implementation of the project - become familiar with the methods and software tools for modeling neurons and networks - use the selected agentic AI system to design and implement simulations and analyze the results - evaluate the performance of the AI system in accelerating research	
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Classification of cortical neurons based on experimental data	Neurons of the nervous system display considerable variability in terms of their shape (morphology), spontaneous and input-driven physiological behavior, and molecular composition (markers). Based on these characteristics, neurons are grouped into cell types which are thought to have distinct functions. Experiments carried out at the Institute of Experimental Medicine have yielded a large database of the anatomical and physiological features of hippocampal cells. Using this database, we aim to determine the number of different cell types in the mouse hippocampus, and to identify the relations between different types of neuronal characteristics, through the application of methods in modern statistics and machine learning. We will also characterize the multi-dimensional variability of cell properties within individual cell classes, and construct populations of model neurons that match real neuronal population not only in terms of their average properties, but also regarding their variability. In the long run, these studies will allow us to understand how the diversity of neurons contributes to the efficiency and robustness of computations in the brain, and may facilitate the construction of artificial systems with similarly robust and efficient performance.	- Review the basic literature on the properties of various hippocampal cell types - Get familiar with the experimental database of morphological and electrophysiological data - Extract useful morphological and electrophysiological features from the data - Classify neurons in the database into cell types and compare their properties - Quantify and model the variability within cell types	Some programming experience is required; knowledge of modern statistics and machine learning methods would be an advantage.
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Real-Time EEG–Motion Coregistration: Technical Implementation and Application to Movement-Related Cortical Activity and Connectivity	The lab has a Brain Products actiCHamp Plus EEG amplifier and access to a Qualisys (QTM) optical motion capture system. Synchronizing these two modalities at the sample level is a non-trivial technical problem: naive software-only approaches do not, by themselves, guarantee sample-accurate temporal alignment between the two acquisition chains. The student will investigate and implement a robust real-time coregistration pipeline for these specific systems, then use it to design and run an experiment examining cortical activity and functional connectivity during movement, using a target group vs. a control group.	1. Get familiar with the actiCHamp Plus and Qualisys QTM systems and their real-time data access and synchronization options (RT protocol, LSL, hardware triggering). 2. Conduct a literature review on EEG–motion coregistration methods and on movement-related cortical activity and connectivity. 3. Design and implement the technical solution for synchronized, real-time EEG–motion data acquisition. 4. Develop an experimental paradigm and protocol for jointly examining movement-related cortical activity and connectivity. 5. Run the experiment with target and control groups and evaluate the results.	Python (or C++) programming. Familiarity with EEG/biosignal processing is an advantage, not a prerequisite.
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Modelling the interactions between Na ⁺ and Ca ²⁺ spikes in CA1 pyramidal neurons	Active dendritic mechanisms greatly enhance the information processing capabilities of single neurons and contribute to behaviorally relevant computations. In the CA1 neurons large dendritic Ca ²⁺ spikes have been observed both in vitro and in vivo, but the accurate biophysical mechanisms of their generation is unknown. In particular, it has been observed that Ca ²⁺ spikes can be triggered by dendritic current injections in vitro, while somatic stimulation only leads to Na ⁺ spikes. However, when somatic Na ⁺ spikes are blocked, Ca ²⁺ spikes can be also triggered from the soma, suggesting a complex and dynamical interaction between these two spike types. The goal of the project is to use simple and morphologically detailed biophysical models to explain these observations and provide a more realistic model of dendritic excitability in CA1 pyramidal cells. This work could reveal fundamental properties of dendrites with possible implications on biological and artificial neuronal networks.	Review the existing literature on dendritic Ca ²⁺ and Na ⁺ spikes in CA1 neurons and their computational models. Simulate dendritic Ca ²⁺ and Na ⁺ spikes in a biophysical model of CA1 neurons, previously developed in the lab. Modify this model to test simple hypotheses on the potential mechanisms explaining the interaction between Ca ²⁺ and Na ⁺ spikes.	basic neurophysiology, statistics, python programming, good english language skills
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Geometry of drift in hippocampal spatial codes	The neuronal response to the repeated presentation of identical stimuli is never exactly the same - it is in fact highly variable, while the perception is remarkably stable. In this project we are interested in characterising this variability, including its possible benefits and limitations for learning, memory and navigation. Specifically, during navigation in virtual reality the hippocampal code for space changes from day to day, a phenomenon called representational drift. Our goal is to study the hypothesis that the representational drift is not completely random, but avoids certain directions in the state space. This would enable the system to quickly learn novel information while also maintaining stable representation of earlier memories.	Review the recent papers analysing representational drift in the hippocampus and related cortical areas with special emphasis on the methods to characterise the directionality of the drift. Develop novel analysis methods to detect systematic components of the drift and test these methods on synthetic data. Finally, apply the analysis techniques to real data recorded in mice navigating in virtual reality environments.	interest in neuroscience and deep learning, strong mathematical background especially in linear algebra, programming in Python
Plasticity of hippocampal spatial representation during navigation in virtual reality	Navigating in a novel environment or learning new information in a familiar one requires adaptive neuronal representations. Recent findings identified biophysical mechanisms, behavioral time scale plasticity or BTSP events, that can cause sudden changes in the spatial tuning of hippocampal neurons. However, it is unclear if these BTSP events are necessary and sufficient for all forms of representational changes. In particular, it is not known how repeated BTSP events during place field traversal influence the stability of existing place fields. Building on our recently developed scheme to detect potential BTSP events, the student will develop methods to analyse place field stability and predict lap by lap place cell activity.	Review the recent papers analysing plasticity of hippocampal place fields with special emphasis on the methods to characterise lap-to-lap changes due to behavioral time-scale plasticity (BTSP) or representational drift. Develop novel analysis methods to predict place cell activity in a given lap based on activity history and behavioral variables. Validate and test the method on synthetic data. Finally, apply the analysis techniques to real data recorded in mice navigating in virtual reality environments.	basic neurophysiology, statistics, Python programming, good English language skills

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Agent-based modelling of epidemics	The spread of the COVID virus is posed unique challenges to researchers and governments alike. Our work focuses on the development of PanSim a parallel C++ programming framework that can simulate the spread of COVID with an agent-based solution, and the scaling of our databases to enable simulations of the entire country. The challenge will be to try and capture the complexity of the society - represented by various statistical metric collected during the 2021 census, and generate a representative synthetic population. The work takes place within the ITK epidemiological modelling group, and the newly awarded AURORAI Horizon2020 project, and has the potential to continue into thesis work as well as a student research competition entry.	- Exploration of KSH, GIS databases (households, agents, occupations, commuting) - Putting relevant data into a structured form - Building an agent population, by metric, with subsequent corrections	None, python is recommended
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AI-Driven Optimizations for High-Performance Stencil Codes	This project explores the integration of artificial intelligence (AI) techniques into compiler optimization workflows for high-performance computing (HPC) applications, specifically focusing on stencil codes operating on structured meshes. By leveraging domain-specific knowledge inherent to stencil computations, such as spatial locality and repetitive patterns, the research aims to develop AI-driven models that optimize code generation, improve execution efficiency, and adapt to diverse hardware architectures. The project will address challenges in optimization space exploration, parallelization strategies, and performance tuning for heterogeneous computing environments.	- Literature Review and Problem Analysis: Investigate existing AI-driven compiler optimization techniques and their application to HPC codes. Analyze the unique characteristics of stencil computations on structured meshes and identify optimization opportunities. - Using AI Models for Compiler Optimization: Experimenting with LLM models to predict optimal compiler transformations (e.g., loop tiling, fusion). Incorporate domain-specific features such as data locality, memory access patterns, and computational dependencies. - Implementation and Integration: Integrate the developed AI models into an existing compiler framework (e.g., LLVM). Implement a feedback-directed optimization loop to iteratively refine performance based on runtime profiling. - Performance Evaluation: Benchmark the optimized stencil codes across various HPC architectures (e.g., CPUs, GPUs). Compare performance improvements against traditional compiler optimizations in terms of execution time, energy efficiency, and scalability.	C++
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Experimental investigation of cell-cell interactions in yeast colonies	Combining different investigation methods of cell-cell interactions, we are aiming to understand the behavior of multicomponent microbial populations. Spreading or extinction of individual strains will be studied with respect to local interactions, initial cell concentration and spatial structure. In this interdisciplinary project bioinformatics, comparative genomics and microbial experiments are combined to investigate how the cell's environment and its interactions control the individual's behavior and influence the population. Numerous yeast strains will be investigated by single strain and pairwise co-cultures in different environments (by variation of carbon source and density) to identify fitter strain. Based on these experimental results, mathematical models will be built to simulate interactions and predict multicomponent colonies that can be tested experimentally. The role of yeast in understanding molecular processes has already been remarkable, in our project we would like to get a clearer picture about the colony formation and cellular interactions. Wet lab opportunities include following the growth of yeast cells, modifying their genome and observing the formation of different colony structures. Based on these results a model has been developed to simulate the cellular interactions and the predicted behaviour of multicomponent colonies tested in the lab. Students are offered the opportunity to take part in all parts of the project from the planning, through the implementation, to the evaluation of the results. Individual ideas in connection with the project are	- Familiarize with laboratory procedures. Learn how to prepare media, culture yeast. - Plan and prepare interaction experiments with multiple strains on solid media in multiple environments. - Document experiment and analyse results - Review literature related to research of cell-cell interactions	Knowledge of basic cell biology is required, any experience in wet lab is an advantage
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Development of high-throughput methods to study Yeast co-cultures	Saccharomyces Cerevisiae is an important model organism both for theoretical studies and in industry. In technological settings like the wine or beer industry multiple yeast strains are used in co-cultured. Our goal is to study the behavior of yeast strains in co-culture both in liquid and on solid medium. The Systems Biology laboratory is equipped with a Hamilton Microstarlet liquid handling system to create mixtures in large batches in multiwell plates. To follow processes we also have access to a motorized fluorescent microscope and a plate reader.	1. Literature review: After choosing the specific research goals review relevant literature. 2. Design experiments: The student will have the task of designing experiments. Depending on the strains and experimental conditions (solid or liquid) the student will choose the appropriate instruments (liquid handling systems, plate reader, microscopes etc.) and disposables to be used and the particulars of the experiments. 3. Experiments: Get to know basic laboratory practices and instrumentation needed for the experiments. Take part in running experiments and analyzing data.	
Investigating yeasts in microfluidic chambers	Microfluidic devices make it possible to investigate interactions between individual yeast cells and study their ageing. This project offers an opportunity to develop microfluidic chambers and/or answer biological questions (e.g.: cell-cell interactions, ageing, cell cycle on a single cell level) by the help of such chambers.	- Familiarize with laboratory procedures. Learn how to prepare media, culture yeast and run microfluidic experiments. - Prepare and run microfluidic experiments to test chip design - Document experiment and analyse results - Review literature related to the selected biological process (i.e. aging, cell cycle) and microfluidic methods	basics of cell and molecular biology, lab experience is an advantage

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Analysis of Microscopic Images of Yeast Colonies	In this project, we investigate interactions between yeast colonies by expressing fluorescent proteins of different colours in different strains and then co-culturing them on solid media. These colonies are examined using fluorescence microscopy from a top-down view and in cross-section. Based on the colours, we identify the strains and infer their spatial distribution, the extent of interaction, etc. The student's task mainly involves image processing, specifically the identification and quantification of individual strains within the photographed colonies. There is also the possibility for the student to participate in the experimental, microscopic work if they wish.	- Familiarize yourself with the established experimental setup. - Learn the image processing methods currently used in the laboratory. - Develop an image analysis method for the separate quantification of cells marked with different colors in the images. - Document the developed code.	
What's going on in the microbiome: Understanding gene-regulation dynamics with AI	This project focuses on developing advanced AI models to predict and understand gene expression within microbial communities, with implications for health diagnostics, ecosystem management, and synthetic biology. The project goal is to develop novel genomic language model-based solutions to understand the underlying gene-expression process in microbiomes. This is crucial, since obtaining transcriptome data is challenging both computationally and experimentally, therefore delivering efficient models could greatly improve our capability of understanding the engineering systems. The goal is to develop a new, multimodal AI model for gene prediction from a genomic context. Keywords: Multimodality; multiomics; transcriptome analysis; generative models; gene expression; pytorch; NGS	Understanding and reviewing relevant literature; Using NGS pipeline; model training and evaluation	

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Gene prediction revisited	"This thesis aims to revisit the challenge of gene prediction by using the advancements in transformer-based neural networks and genomic language models. With the increasing availability of genomic data, a vast portion remains unexplored, leaving numerous genes and proteins unidentified. This research intends to apply cutting-edge genomic language models, trained on extensive sequence datasets, to address the limitations of current gene prediction methods. The project will focus on developing a more robust, generalizable tool capable of uncovering new insights into the genetic fabric of uncharted genomes. Students will explore the application of these advanced AI techniques to improve the accuracy and efficiency of gene prediction, potentially improving our understanding and identification of novel genetic elements across diverse species. The ultimate goal is to contribute to the broader bioinformatics field by providing a sophisticated approach to predict and annotate genes in newly sequenced genomes, thereby facilitating further biological discoveries and advancements. Keywords: molecular biology; deep learning; genomic language models; pytorch; HPC	Understanding and reviewing relevant literature; Development of gene prediction algorithms based on genome sequence representations	
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Rotating plate design and programming for metamaterial characterization	In the past ten years, a new interdisciplinary field known as metamaterials research has emerged. The core concept driving this area of research is that the behavior of electromagnetic waves interacting with materials is influenced not only by their chemical composition but also by their geometrical structure, which can lead to unique properties not found in bulk materials. Metasurfaces have a wide range of applications, from microwave to optical frequencies. The aim of this project is to create a rotating platform for the evaluation of metasurfaces.	Comprehend the fundamental principles of metamaterials. The student's assignment involves designing and coding the functionality of the rotating platform. The functionality of the measurement setup will be showcased through the analysis of existing metasurfaces.	Basic concepts of STEM. CAD design and microcontroller programming.
Functional metasurfaces for sensing / Metamaterial Resonator Based Microwave Sensing for Biological Application	During the last decade novel interdisciplinary scientific area, the research of metamaterials emerged. The fundamental idea behind the metamaterial research is that the interaction of electromagnetic waves with matter is governed not only by the chemical composition, but structuring can produce novel properties, not available in bulk form. The research field of metamaterials extends the limits of subwavelength imaging, makes possible to cloak scattering objects, can enhance the performance of antennas and can increase the sensitivity of sensors. Nowadays the research of metamaterials advanced to a level, where commercial applications are underway. In this research project laboratory the student will investigate the applicability of metasurfaces for sensing purposes especially fluid sensors, which can be assembled in lab-on-a-chip configuration.	Elektromágneses rezonátorok, metafelületek tervezése, azok megvalósítása a Karon elérhető gyártási eljárásokkal. Az elkészített eszközök elektromágneses jellemzése és fluidikai eszközökbe való integrálása.	Good marks in physics, programming and math.

Electromagnetic software development for metamaterial research on high performance computing platform	The goal of the projects is to develop Maxwell equation solvers and graphical user interfaces specially designed for metamaterial research. A set of freely available Parallel Finite Difference Time Domain, Finite Element and Method of Moments codes will be developed to simulate the propagation of electromagnetic waves in metamaterials and photonic crystals. The algorithms will be supplemented with homogenization procedures for metamaterials and composites.	Electromagnetic field computation software development for metamaterial and photonic crystal design, which can be run a supercomputer.	Software development in C++, Python or Matlab. Basic understanding of electromagnetics and scientific computing.
3D printed metamaterial design	During the last decade novel interdisciplinary scientific area, the research of metamaterials emerged. The fundamental idea behind the metamaterial research is that the interaction of electromagnetic waves with matter is governed not only by the chemical composition, but structuring can produce novel properties, not available in bulk form. The metasurfaces can have several applications from the microwave to the optical frequencies. At microwave frequencies, fluids containing polar molecules exhibit a high electric permittivity. Thus, the focus of this study involves exploring metasurfaces and metamaterials composed of fluidic channels and subwavelength reservoirs. The student is tasked with designing such metasurfaces that can be produced using 3D FDM printing.	Understand homogenization techniques and extract effective electromagnetic parameters of metamaterials. Investigate metasurfaces where the geometry of the fluidic channels is inspired by space filling curves. By fine tuning the geometrical parameters required electromagnetic parameters should be achieved. The task of the student includes generating input files for 3D printing and performing sample characterization through measurements.	

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Investigation of Silver nanoparticle containing wound dressing hydrogels for Ag release and skin penetration in microfluidic chips	Our partners from Ukraine provided us with two different hydrogels which are currently used for wound therapy for soldiers. This hydrogels are funtionalized with silver-nanoparticles for anti-septic/antibiotic effect. Our study would like to demonstrate the release and skin penetration of active components (silver-nitrate) from the formulation in microfluidic diffusion chambers on human skin. We are looking for students to perform microfluidic studies.	Training for using skin-on-a-chip devices. Testing hydrogel #1 in chip on synthetic membranes (release) Testing hydrogel #1 in chip on human skin samples (penetration) Testing hydrogel #2 in chip on synthetic membranes (release) Testing hydrogel #2 in chip on human skin samples (penetration) Evaluation and explanation of the results.	
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Compression simulation software development for pharmaceutical use	in the pharmaceutical industry, solid dosage forms currently account for the majority of the preparations used. The tablet as a dosage form forms the basis of many preparations (even innovative preparations) (traditional, compression-coated, multilayer tablet systems, compression products containing liquid elements, effervescent tablets, ODTs). The use of compression simulators and the analysis of compression force curves are essential for tabletting design. The elastic, plastic and fragmentation behavior of materials can be characterized by analyzing the curves. The thesis aims at the mechanical and IT background of this. The candidate performs the laboratory tasks using the Diaf eccentric tabletting machine and the Natoli NP-RD10A compression simulator located at the Faculty of Pharmacy of Semmelweis University. The aim of the practical work is to equip an eccentric tablet press - used in compression tasks - and to write a related program, with the help of which tablets with precisely designable parameters can be compressed, knowing the compression force curves. We are looking for applications from students who are receptive to mechanical engineering tasks.	Summary of basic compression knowledge Operating mechanism of compression simulators Options for recording compression force curves Solutions for tabletting machine instrumentation Software development for recording compression force displacement	
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Human and Pig Native Excised Skin Preparations for In Vitro Penetration and Permeation Studies	For the separation of epidermis (consisting of stratum corneum and viable epidermis) and dermis mechanical, thermal, and chemical techniques are available. Dermatomed skin can be prepared by means of an electrical dermatome which performs surface parallel sections, composed of the epidermis and including the stratum corneum as well as parts of the dermis. Normally, a slice thickness of 200–400/500 µm is recommended for human skin (OECD 2004b; USEPA 2004). In doing so, the hair follicles will be cut, but the resulting holes will rapidly close during incubation with the acceptor medium due to swelling of the tissue, especially if aqueous donor and receptor fluids are used. During dermatomization care must be taken to avoid mechanical damage of the SC, the main barrier of the skin. To overcome this problem, protection of the skin surface by a plastic foil is indicated (Brain et al. 1998). Typically, dermatomed skin is used for permeation studies, especially if the influence of the hydrophilic layers of the epidermis and dermis should be considered on skin absorption (influence of partition step between SC and viable epidermis/dermis). Moreover, dermatomed skin might be of particular interest to study the fate of very lipophilic drugs (e.g., pesticides) due to the limited solubility in rather the hydrophilic viable epidermis and dermis and for cosmetic products.	- to purchase pig skin from the butchers - to purchase human skin from plastic surgery - to make dermatomed skin samples from the full thickness skin (different thickness: only epidermis, epidermis+dermis, full thickness skin) - to make basic comparative permeability experiments in skin-on-a-chip microfluidic diffusion chambers - for validation use 2% caffeine cream - measure the caffeine content of the perfusion samples with NanoDrop Spectrophotometer	
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Development and validation of eye-on-a-chip microfluidic systems to study ophtalmological drug delivery	The investigation of ocular drug penetration through the biological barriers is a little-studied area. The current ophtalmic formulations are not effective enough due to the low bioavailability (~5%) and insufficient tissue penetration. The eye drops should be applied frequently (5-6 times daily) which is not convenient for the patients. Also the current therapy for retinal disorders (like macula degeneration) is invasive, because intravitreal injections should be applied repeatedly to treat the posterior part of the eye-ball of the patients. In the laboratory of Barrier Modelling and Innovative Pharmaceuticals new, innovative ocular formulations are under development. To evaluate them special microfluidic chambers should also be developed. The task is to test the novel formulation on corneal and retinal tissues incorporated to the mictofluidic chambers.	- to learn and standardize eye ball preparation (cornea and retina dissection) - design and manufacturing of microfluidic chips for this special application - to test one reference formulation (caffeine cream) - to test one novel ophtalmic formulation (nanofiber based insert) - to determine the drug concentration in the perfusion fluids using NanoDrop photometer.	
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Development of novel gene-therapy methods in experimental animal models	One major therapeutic limitation of currently available small-molecule drugs is their limited action specificity. Limited specificity can be exhibited as serious side-effects and as loss of therapeutic potential, especially for diseases affecting the nervous system. Gene-therapy methods have the potential to target specifically cell-types that are causing a particular disease without altering the function of the rest of the nervous system. In this project we will use experimental animal models to test new viral-based gene-therapy approaches by analysing gene-expression specificity across brain areas and cell-types. The candidate will mostly be involved in tissue processing, microscopy and image processing tasks.	Learn the molecular basis of adeno-associate virus mediated gene delivery Understand how to measure virus neutralisation using cell-based assays Learn and perform virus neutralisation measurements	How to apply: Email hillier.daniel@itk.ppke.hu by 5:00 PM on the Monday after the Project Fair. Please include a brief summary of your motivation and your estimated time availability for this semester. We are looking for students with a long-term mindset who are interested in eventually
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Pioneering Early Disease Diagnosis with Deep Learning in the Human Brain	What if we could diagnose debilitating neurological and psychiatric disorders years before the first symptoms emerge? Our lab is developing transformative diagnostic tools that use artificial intelligence to detect the earliest signs of disease in the human brain. We are offering a project to build a state-of-the-art data analysis framework that can identify subtle pathological changes from complex biological signals. This project sits at the intersection of clinical neuroscience and machine learning, focusing initially on retinal diseases that lead to blindness, with the goal of creating a blueprint for the early diagnosis of a broad range of central nervous system conditions. You will collaborate with clinicians and scientists to create a system capable of turning raw patient data into diagnostic-level predictions. The core of your work will be to implement advanced time-series classification methods and deep learning models to achieve unparalleled accuracy in detecting disease.	Your primary responsibilities during the semester will include: Data Collection and Integration: Assist clinicians in recording high-resolution data from patients and model systems, utilizing techniques such as electrophysiology (ephys), functional ultrasound (fUS), and advanced clinical imaging (e.g., OCT). Automated Data Processing: Develop robust, automated pipeline to preprocess and clean data, preparing them for analysis and extracting key features using novel analysis methods. Machine Learning Model Development: Implement, train, and optimize deep learning models designed for time-series classification, aiming to distinguish healthy signals from the earliest indicators of pathology. Performance and Quality Evaluation: Rigorously validate your models against clinical data to evaluate their diagnostic accuracy, sensitivity, and specificity, ensuring the framework is reliable and effective for real-world application.	You are a great fit for this role if you: - Are driven by a deep curiosity for research and take the initiative in your own learning. - Excel at communicating complex ideas through clear and compelling writing. - Possess the self-discipline and motivation to work independently and see challenging projects through to completion.
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Measurement and modification of individual behaviour using embedded systems	Embedded systems readily recognise human faces or objects. Interaction with humans or animals is however a much more challenging - and rewarding - task. How can I, as a programmer, modify the behavior of a living organism? In this project we develop interaction environments for animals and humans and train them for tasks that can report how well they see the world (visual acuity, depth perception, visual prediction). We developed a virtual interaction environment and train subjects with minimal human intervention. In this project, you will learn how to interface hardware elements (arduino, RPi, depth cameras, EEG, reward systems), adapt the environment, design new interaction tasks and analyze multi-modal data.	Understand how to evaluate behavioural performance (e.g. d' and other quantitative measures) Develop training protocols that teach the subject (animal or human) a visual task. Collect and analyse data. Interact with professional trainers and clinicians.	Application: hillier.daniel@itk.ppke.hu, by 5:00 PM on the Monday following the TRP fair event. Briefly outline how much time you intend to dedicate to the project until graduation (covering both the TRP and Thesis Work), what skills you possess, and whether you commit to submitting your thesis material as
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Rewiring the Brain: How Artificial Activation Reshapes Gene Expression	We know that chemogenetics allows us to switch specific neurons on or off—but what happens to the molecular machinery inside the tissue when we do? In this project, you will investigate the transcriptional aftermath of neuronal activation. Using bulk FLASH-seq (a high-sensitivity RNA sequencing method), you will analyze how targeted stimulation reshapes gene expression networks. You will look beyond simple activity markers to identify complex functional shifts, including: Immediate Early Genes (IEGs): The first responders to neural activity. Synaptic & Structural Proteins: How the brain physically remodels itself. Neuroinflammatory Signatures: Investigating potential immune/glia responses to stimulation. Why join? This is a hybrid wet/dry project designed to give you a complete view of the transcriptomics workflow: Wet Lab: You will assist in precise tissue collection and collaborate with the Richter Lab on library preparation. Bioinformatics: You will use a guided analysis workflow to process raw sequencing data, learning how to turn gigabytes of reads into biological insights.	Assist in brain tissue harvesting and sample preparation. Participate in the RNA library generation process (FLASH-seq protocol). Process sequencing data using standard bioinformatics pipelines (QC, alignment, quantification). Perform Differential Expression Analysis to isolate genes regulated by chemogenetics. Visualize biological modules using volcano plots, heatmaps, and pathway analysis tools.	How to apply: Email hillier.daniel@itk.ppke.hu by 5:00 PM on the Monday after the Project Fair. Please include a brief summary of your motivation and your estimated time availability for this semester. We are looking for students with a long-term mindset who are interested in eventually
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Portfolio Optimization with Artificial Intelligence	Computational finance has been one of the most dynamically evolving research fields over the past 75 years. Since the 1950s, optimal portfolio selection has been a central problem and remains highly relevant today. In addition to the traditional risk-return approach, searching for sparse portfolios that maximize mean reversion also belongs to the core problems. Identifying optimal portfolios makes it possible to develop profitable trading algorithms that exploit price convergence, attracting significant industrial and academic interest.	Fitting historical market data to Vector Autoregressive (VAR) mathematical models Studying and implementing financial mathematical models Development of efficient trading algorithms Testing trading algorithms on synthetically generated and historical datasets Statistical evaluation of the results and comparison with the scientific literature	Basic programming skills (e.g., Python, MATLAB, or Java) Overview of machine learning and clustering methods Application of statistical comparison and data analysis methods Understanding and summarizing English-language scientific literature
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Pricing Financial Options with Artificial Intelligence	Computational finance has been one of the most dynamically evolving research fields over the past 75 years. One of the most studied areas is the pricing and risk management of complex financial products such as futures and options. The Nobel Prize-winning Black–Scholes option pricing model of the 1990s has received new momentum with the advancement of neural networks, machine learning, and other AI algorithms. Within the framework of the lab, students will have the opportunity to research these methods under professional supervision.	Review of the scientific literature on non-parametric option pricing models Overview and application of machine learning methods to the option pricing problem Development of efficient trading algorithms based on option pricing models Testing trading algorithms on synthetically generated and historical datasets Statistical evaluation of the results and comparison with the scientific literature	Basic programming skills (e.g., Python, MATLAB, or Java) Overview of machine learning and clustering methods Application of statistical comparison and data analysis methods Understanding and summarizing English-language scientific literature
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