3D CAPTURING OF A SWIMMER

Assignment

This assignment is inspired by a case at Innosportlab Eindhoven where Sioux LIME cooperates with. Innosportlab works with world-class swimmers and aims at making them faster leveraging technology.

The specific question we are considering here is the following: can we make a 3D-analysis of a (world-class) swimmer based on camera video data taken from 6 under-water cameras? Can we do this marker-free, so without putting markers on the swimmer?

Solving this full case in a single internship seems too much of a challenge. However, we can break this down and look at specific parts of the solution and explore promising directions to pursue. One of these directions is to use a simulation/ virtual environment for this and subsequently use a machine learning based approach for the task at hand.

Internship overview

- Master Student
- Graduation Assignment
- Mathware
- Location: Eindhoven

Technologies

- 3D
- Pose Estimation
- Deep Learning
- Simulation

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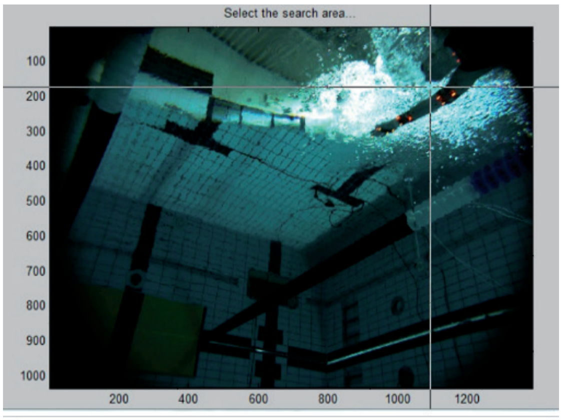
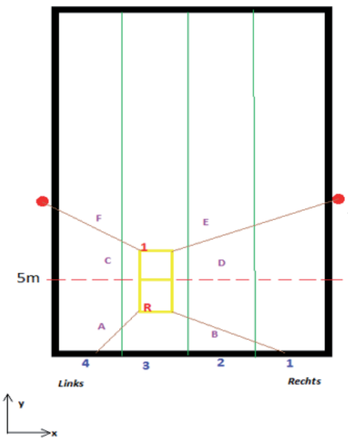
How to setup such a virtual environment? How to apply it for learning? How should the machine learning model look like? What would a simpler task to start with and can we demonstrate that it works? What is the state-of-the-art in pose estimation and how can we successfully apply it to a case like this?

In this assignment we can look at any of these questions. We can formulate a specific assignment that both fit our and your interest at the moment of application.





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Get in touch!
Would you like to know more about this student assignment?

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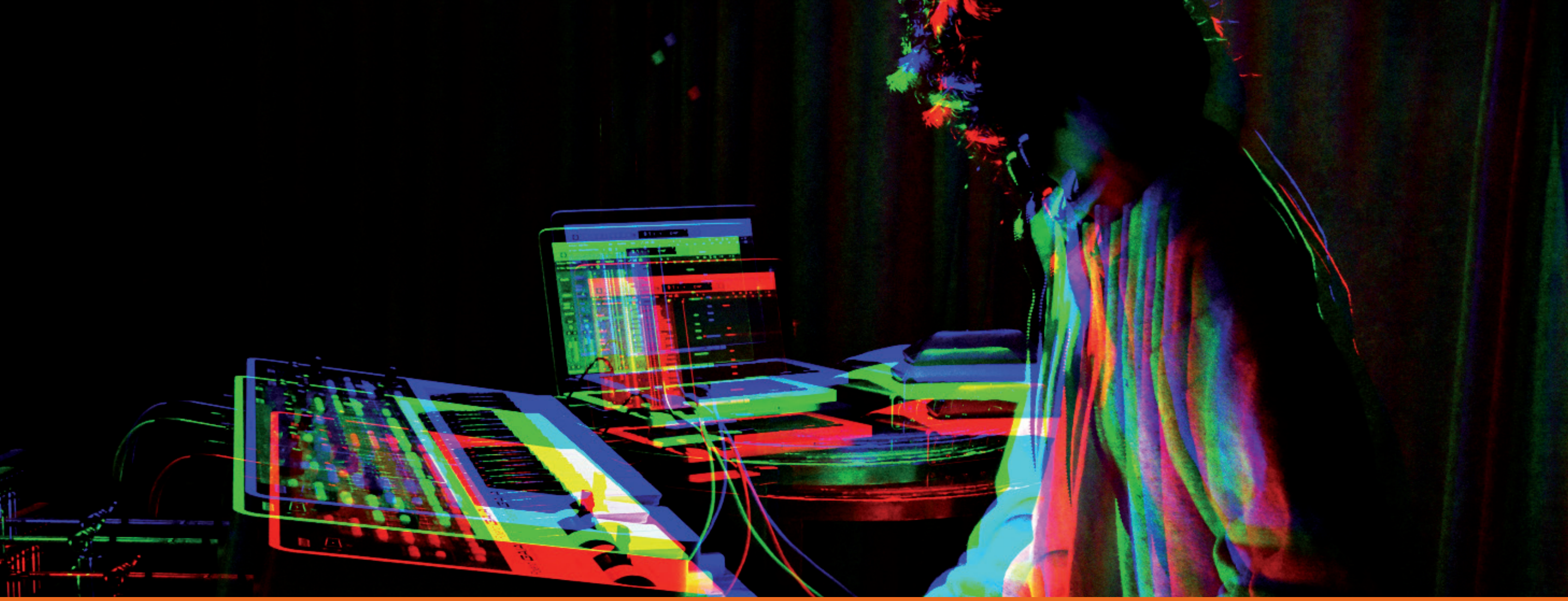

3D DEEP LEARNING

Context

Deep Learning has made huge steps over the last years and is successfully applied in different application domains. Computer vision is probably the domain with the most successful deep learning applications so far. The state-of-the-art is still progressing at a high-pace.

Assignment

In this internship we explore the state-of-the-art in deep learning for 3D image data. Machine learning techniques for this type of data have great potential as our world is inherently three-dimensional and even four-dimensional when considering the temporal domain.

3D data can be represented in different formats such as multi-view RGB(D) images, volumetric, polygonal mesh, point cloud or primitive-based CAD models. As a special case, we also want to look into so-called 2.5D data (also called “2D+Z”). A related question is also how one effectively analyzes 4D data (3D plus time dimension). The extra dimension introduces large computational and memory overhead that quickly is a bottleneck for applying deep learning successfully to these type of data.

Internship overview

- Master Student
- Graduation Assignment
- Mathware
- Location: Eindhoven

Technologies

- Deep Learning
- 3D data
- Computer Vision
- Segmentation
- Object detection
- Python
- Tensorflow

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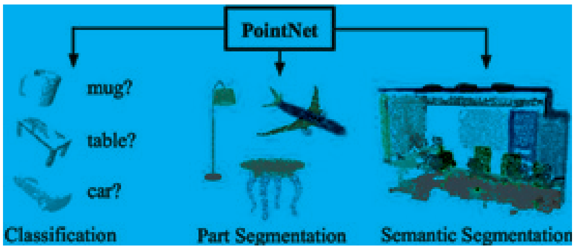
Specific tasks for 3D Deep Learning that we are interested in are classification, object detection and semantic segmentation. Recent literature suggests various deep learning based approaches: volumetric CNNs, multi-view CNNs, spectral CNNs, feature-based DNNs, point cloud DNNs

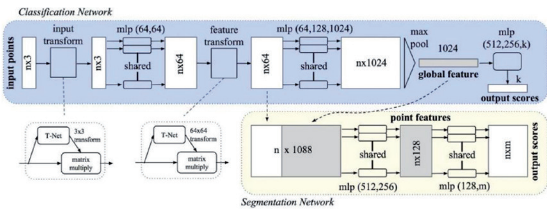
Goals

After having familiarized yourself with deep learning, your goals for this internship are:

- Explore and understand the state-of-the-art models for 3D Deep Learning.
- Study the pros and cons of suggested approaches on a number of aspects.
- Apply state-of-the-art models to datasets (training and testing).
- Potentially: develop a new model or improve an existing model.

There are several open datasets at your disposal that you can work on. Technology-stack to be used:
Python, Jupyter Notebook, TensorFlow, Keras and PyTorch.





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DERIVATIVE FREE OPTIMIZATION

Assignment

Sioux Mathware has its own derivative-free optimizer for (non-linear) least squares problems. This is works much better than a gradient-based solver when fitting parameters of expensive models/simulators for which derivatives are not easy/cheap to compute. In this assignment, we want to improve the performance and robustness of this solver adding an element of Gaussian process regression. Gaussian processes form the basis of a class of optimizers that is also popular for problems like hyper parameter tuning of machine learning models. These commonly don't exploit least-squares structure and leave a lot on the table therefore.

Activities

The student will extend the Python implementation of the existing solver with a notion of uncertainty through the use of Bayesian modeling. The resulting solver is to be compared with the old version and also a basic Gaussian process regression-based optimizer on a set of benchmarks coming from machine learning. Translation of the Python code to C++ is also a valuable activity.

Internship overview

- Master Student
- Internship
- Mathware
- Location: Eindhoven

Technologies

- Derivative free optimization
- Gaussian process regression
- Non-linear least squares

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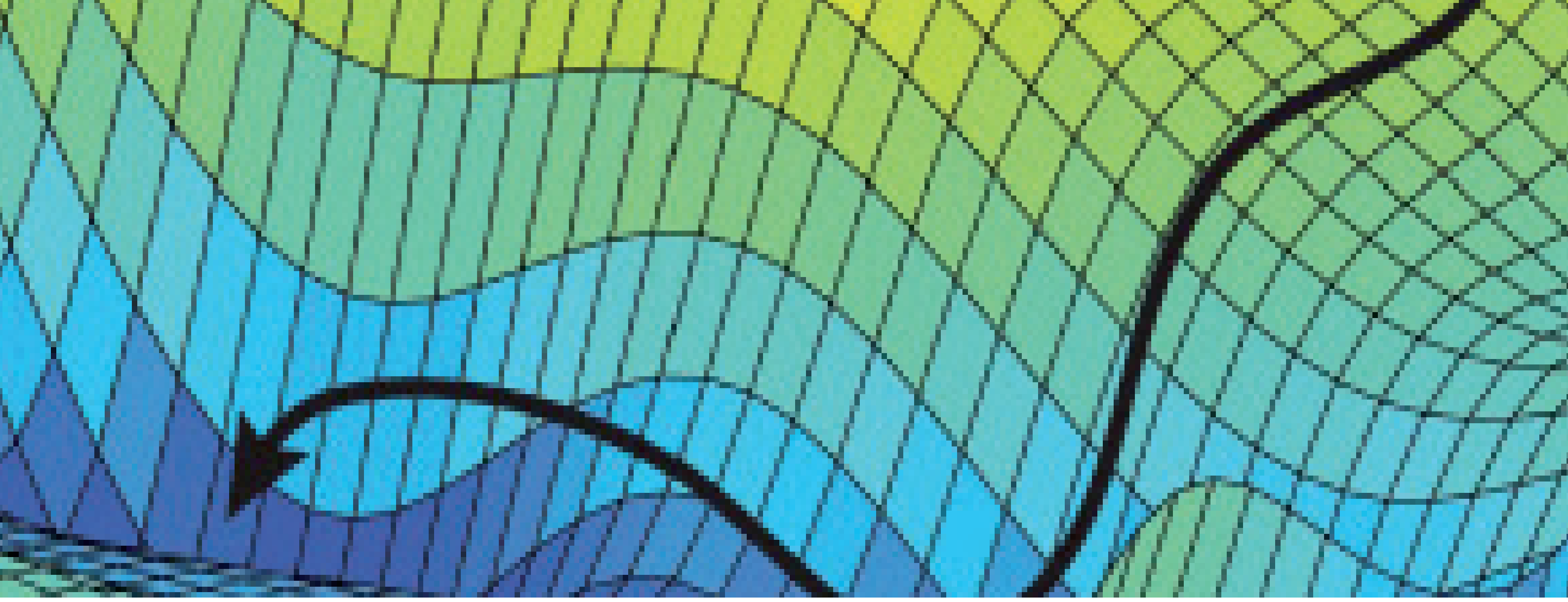

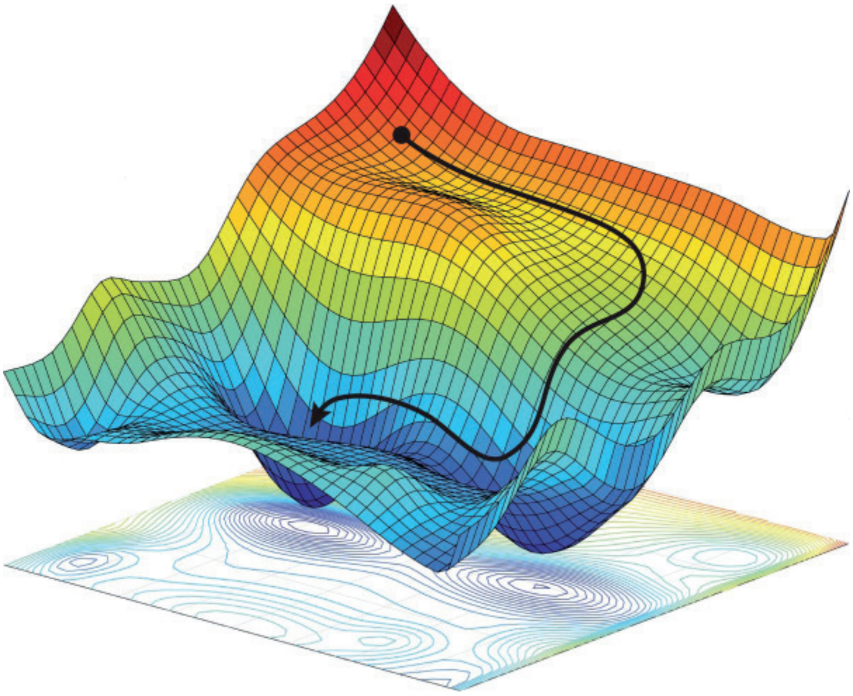

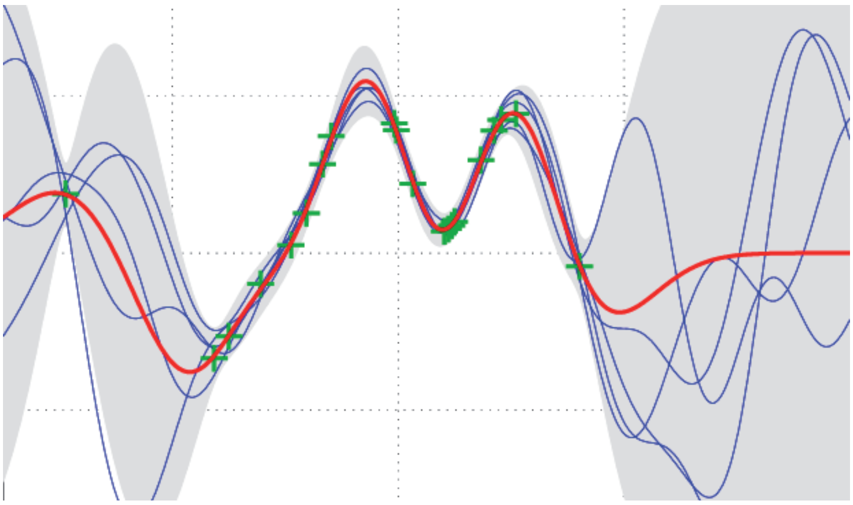

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IMAGE SUPER-RESOLUTION

Assignment

Image super-resolution (SR) techniques reconstruct a higher-resolution image or sequence from the observed lower-resolution images. Although it looks solved and easy in the CSI movies, it is an ill-posed problem, with plenty of open questions. As super resolution is normally only a pre-processing step, it is crucial to have it fast.

Activities

In this project, you will get familiar with state-of-the-art resolution enhancement techniques and implement the most promising ones for our application.

Internship overview

- Master Student
- Internship
- Mathware
- Location: Eindhoven

Technologies

- Computer vision
- Deblurring
- Superresolution
- Image denoising
- Deep Learning

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Context

Along with comparing different techniques (based on interpolation or Deep Learning techniques, i.e. GANs) the important questions are:

- How generalizable the methods are? What happens if they are applied to the kind of images not seen in training?
- How to approach cases with no high resolution images available?
- How to deal with low amount of ground truth available?

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MACHINE LEARNING ON EDGE DEVICES

Assignment

Machine learning (or better: Deep Learning) has become a standard in the industry. Applications such as facial recognition in video surveillance and object classification in spam filtering are real time processes and are deployed in a wide range of devices everybody uses today, like your smart-phone or cameras.
Intuitively, a GPU should do the job, but it requires a lot of interaction with the CPU. This calls for low-latency architectures. One example is the Field Programmable Gate Array (FPGA) devices. Along the FPGA programmable logic, it integrates ARM processors, and RAM to optimize latency.

Activities

In this internship you will explore the frameworks for deploying ML models on edge devices.
Leading manufacturer in the field of FPGAs is Xilinx (Vitis-AI), but Coral.ai TPU (TensorFlow-Lite) is another type of edge device, which may compete with the GPU AI inference products by NVIDIA (TensorRT).

Internship overview

- Bachelor / Master Student
- Internship
- Mathware / Electronics / Technical software
- Location: Eindhoven

Technologies

- Computer vision
- Deblurring
- Superresolution
- Image denoising
- Deep Learning

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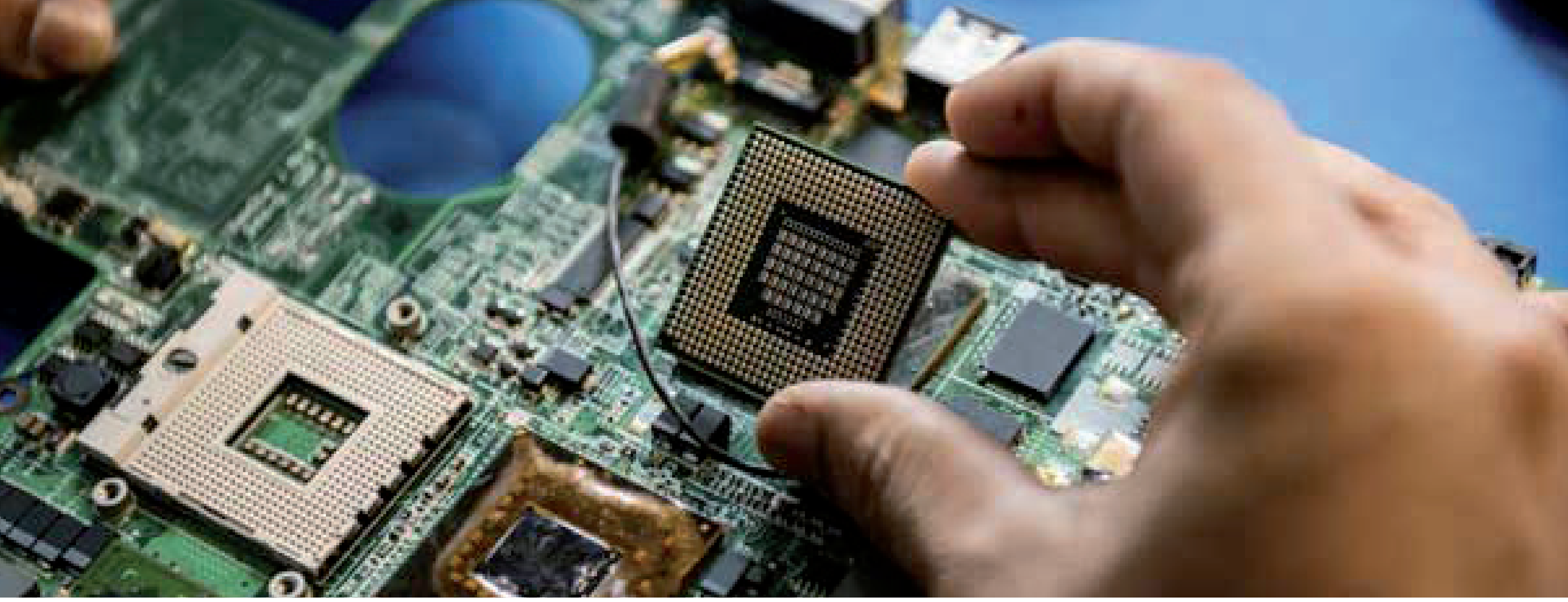
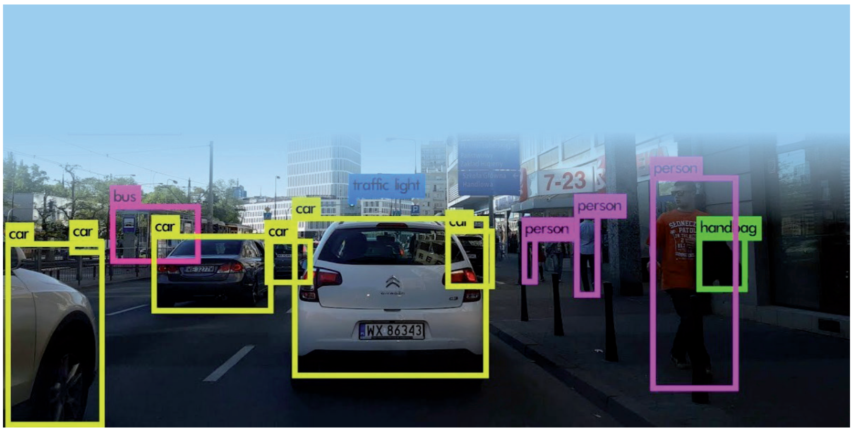


Context

We use high-level languages in the deployment of the latest ML models and image processing on the FPGA boards. A typical ML project consists of two phases. The first optimizes the weights in the model and the second is the inference phase, in which the trained model is deployed on the FPGA device.
The big difference with developing for CPU and GPU is that programming an FPGA device is harder and requires more steps. But recent trends show that manufacturers abstract all the programming to higher levels using languages such as Python, OpenCL and C++. This means that most of the low-level programming is hidden, and therefore, hardware has become accessible to the engineer without much knowledge of FPGAs.



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Get in touch!
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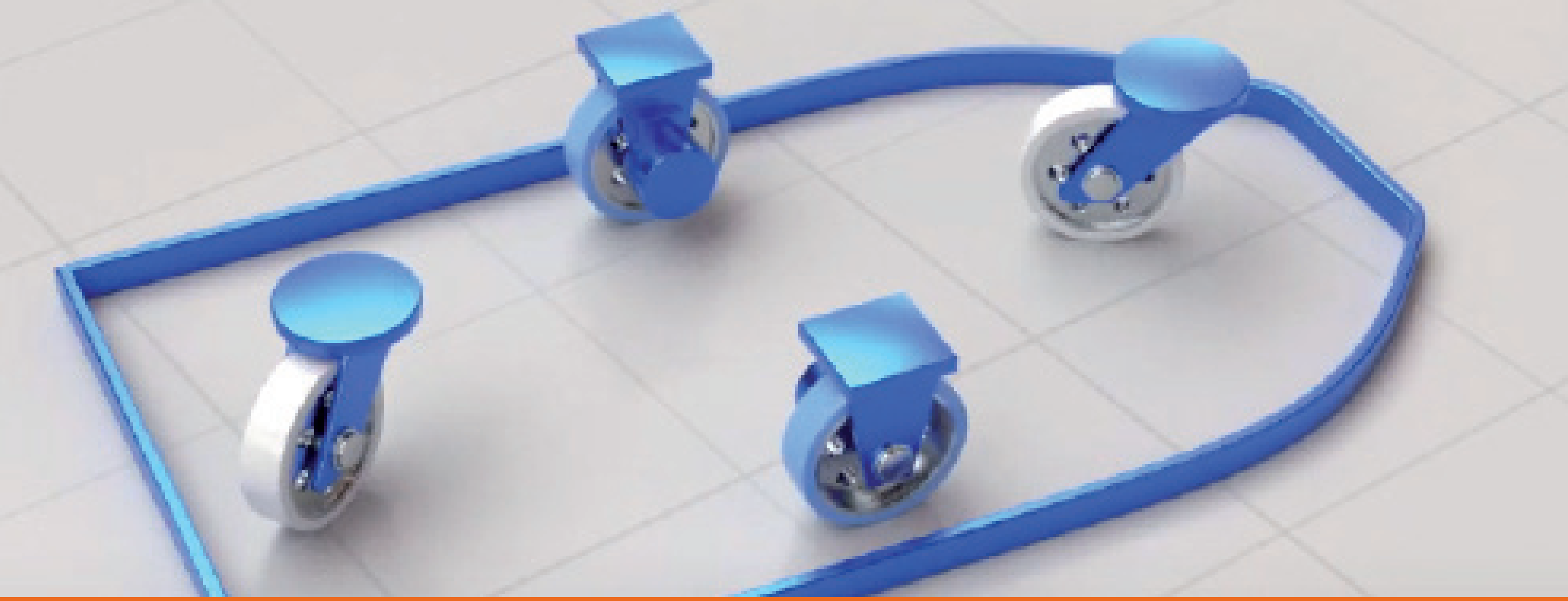


MOBILE ROBOT PATH PLANNING

Assignment

Autonomous mobile robots (AMRs) are the modern and smarter brother of the Automated Guided Vehicles. Both are vehicles that can be used to automate transportation in warehouses. Many types of hardware designs exists, with many different types of steering concepts. Apart from a car-like steering concept, differential drive is a popular concept that allows in-place turning. Other concepts can even move sideways (= ‘crabbing’). In this assignment, we do path planning (which physical path to take) and trajectory generation (which velocity at each point along the path) for multiple steering concepts to assess the impact of the steering concept on the warehouse throughput. An optimal balance between speed/throughput and use of floorspace (including safety margins) needs to be found.

Internship overview

- Master Student
- Internship and/or Graduation
- Mathware
- Location: Eindhoven

Technologies

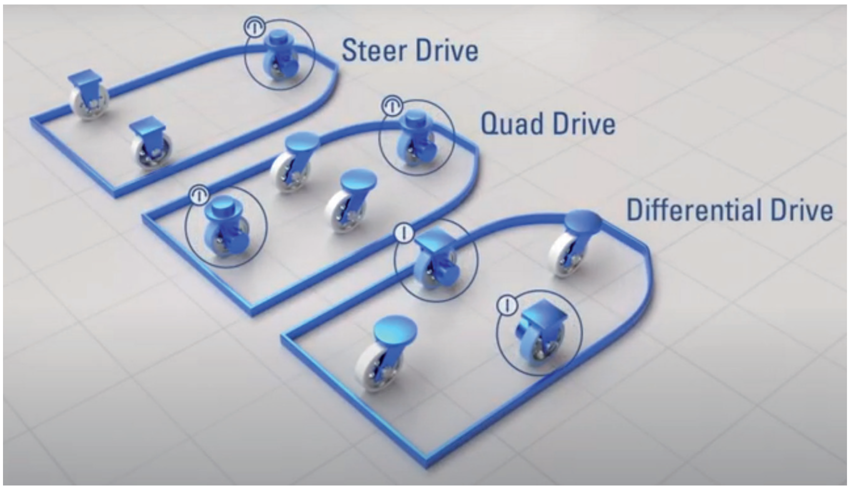
- Autonomous Mobile Robots
- (Non-holonomic) Path planning
- Trajectory generation
- Mathematical Optimization

Activities

The student is to implement models for several steering concepts. Consequently, per steering concept and for a selection of typical AMR maneuvers, path planning and trajectory are to be performed as optimization problems that optimize the throughput/floor space balance.
The steering concepts need to be evaluated and compared .The implementation language is free to choose, but good candidates are MATLAB, Python or C++ with ROS.

Context

Some features that need to be accounted for are velocity and acceleration limits of the carts, the friction with the floor, the safety bubble for emergency stopping, known/unknown loads that the cart might be carrying etc.



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OPTIMAL DESIGNS WITH TOPOLOGY OPTIMISATION

Assignment

Develop a topology optimisation algorithm based on level-set methods that is able to interact with a finite element model and use it to find optimal designs for eigenfrequency maximisation.

Activities

- Develop a structural finite element model
- Implement a topology optimisation algorithm with a solver oriented to take eigenfrequencies as cost functions
- Development and testing of code for benchmarks and toy models
- Learn the theory and foundations behind topology optimisation, and compare the developed algorithm with alternative methods
- Apply the algorithm to a valuable industrial case

Context

Finding the most efficient design for complex structures is a challenging task of enormous industrial importance. Traditional approaches usually focus on simple and easy manufacturable geometries, and the best design is sought by varying a few parameters of an initial design concept. This type of approach explores only a small subset of design possibilities and limits the maximum achievable performance of the final design.

Internship overview

- Master Student
- Graduation
- Mathware
- Location: Eindhoven

Technologies

- Topology Optimisation
- Finite Element Analysis
- Design Optimisation
- Structural Mechanics

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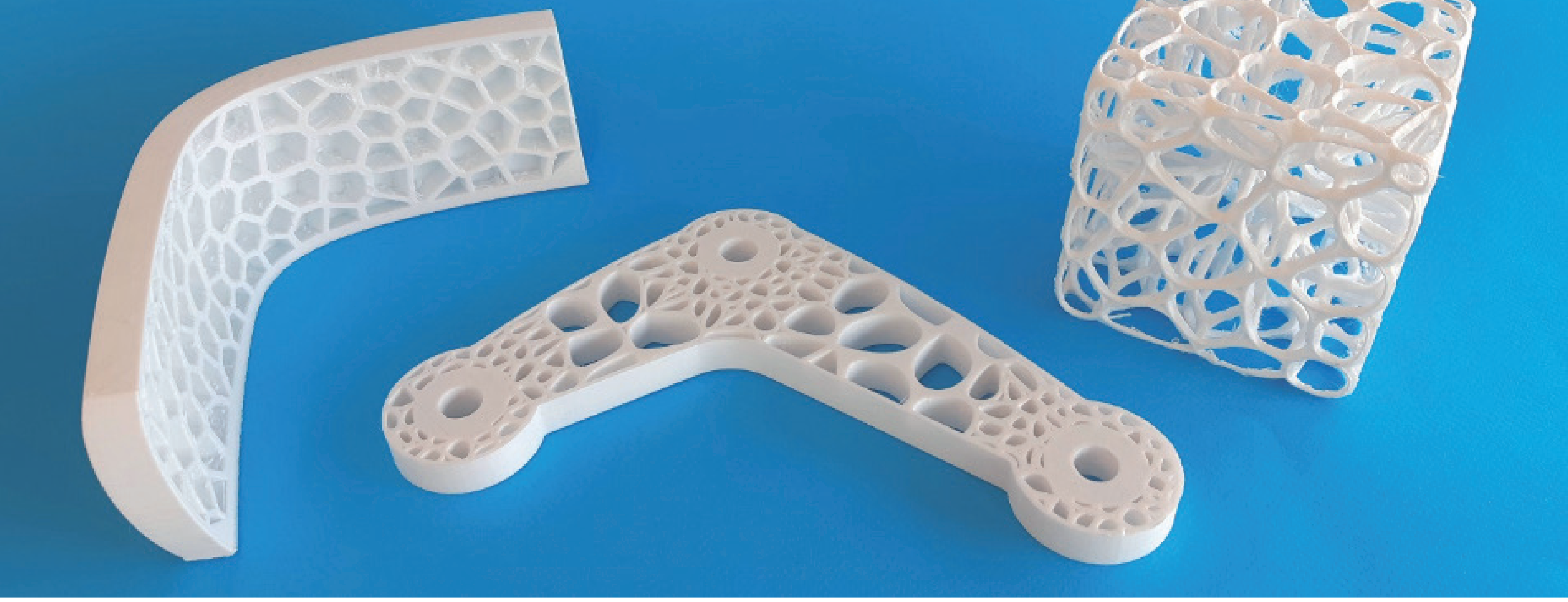

Topology optimisation presents a radically different method that does not rely on predefined design choices but focusses instead on optimising a performance criterion and considering all possible designs that meet the physical and geometrical constraints. By adapting the material distribution on a fine mesh over successive FEM simulations, the best designs that maximise stiffness, minimise weight or reduce vibrations are found.

Due to the discreteness of the mesh elements, typical optimal designs display artificial "Lego brick" textures and jagged edges, and even blurry material-void interfaces for density based methods. To handle these issues, level set methods have been suggested as alternative methods providing smooth void-material interfaces. In these methods, the geometry of a structure is represented by a level set function, and its surface is sharply defined by the zero level contour, which discards the need for post-processing of optimal solutions.

Sioux is in the process of acquiring expertise in topology optimisation and developing algorithms to find the most efficient designs for industrial projects. A particularly important challenge is to find structural designs that reduce the impact of vibrations. When a structure is exposed to sudden accelerations, undesirable vibration modes can be excited. These vibration modes are intricately connected to the design geometry, and with topology optimisation we aim to find designs where vibration modes are damped quickly.

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OPTIMIZATION FOR AUTOMATED PACKAGING

Assignment

The goal of this intern project is to design and implement an appropriate method to optimize a(n) (ideally generic) packaging machine aiming to also make use of product inflow predictability.

Context

Sioux Technologies has developed for one of its clients a solution that concerns real-time optimization algorithms for the automated packaging of products by robots. Both the packaging boxes and the different types of products flow on conveyor belts, leaving a limited amount of time for the robots to perform packaging each product. The algorithm controls the actions of the robots, determining in which order the products should be packed and which product should go in which box.

Typically, given the machine setup, the objective function is to minimize the number of products that leave the conveyor belt unpacked. There are also several constraints that should be taken into account, for instance, each box should contain the correct number of each type of product. An important other type of constraint is that everything should perform real-time. This makes that the algorithm should be fast and even

Internship overview

- Master Student
- Graduation Assignment
- Mathware
- Location: Eindhoven

Technologies

- Optimization
- Scheduling

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faster with an increased speed of the conveyor belts. There is obviously a commercial incentive to use higher belt speeds.

Our developed solutions perform a last-minute optimization, taking into account (only) all the products that are currently on the conveyor belt. However, the flow of products is typically quite predictable. How can we use this to better optimize the packaging? This requires rethinking the current optimization approach. A second goal is to design a(n) (meta) algorithm that solves a more generic case. For instance, up to now LIME has developed two algorithms for two different machine types and these two algorithms partially differ. As an illustration of a more generic algorithm, imagine that the algorithm can handle any specified number of robots. As a nice-to-have, we would like to obtain a bound on the performance of the algorithm. This would enable us to tell how far the algorithm is maximally off the (in hindsight) optimal solution.

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QPS FOR MACHINE CONTROL

Assignment

State-of-the-art control strategies are often formulated as quadratic programs, a class of mathematical optimization problems. Solving medium-sized QPs in 1-10 milliseconds is key to achieve real-time performance in the presence of fast dynamical systems. The Mathware department of Sioux Technologies develops highly efficient QP solvers for the industry. This internship will consider one or multiple open problems regarding non-linear constraints, (approximate) constraint pruning and/or exploiting model predictive control structures.

Activities

The student is will develop algorithms to solve quadratic programs arising in control problems efficiently. The algorithms can be implemented in MATLAB, Python, Julia, C++ or a combination.

Internship overview

- Master Student
- Internship / Graduation
- Mathware
- Location: Eindhoven

Technologies

- Quadratic programming
- Model Predictive control
- (Non)-linear inequalities

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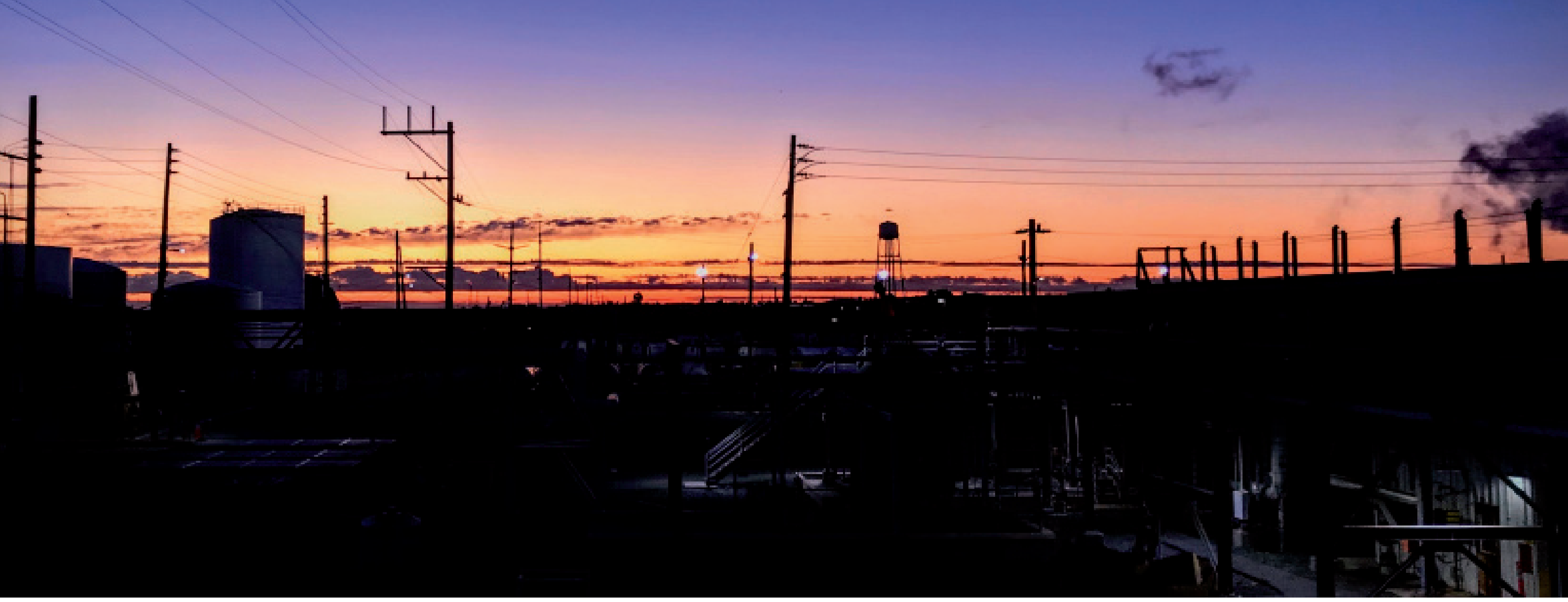
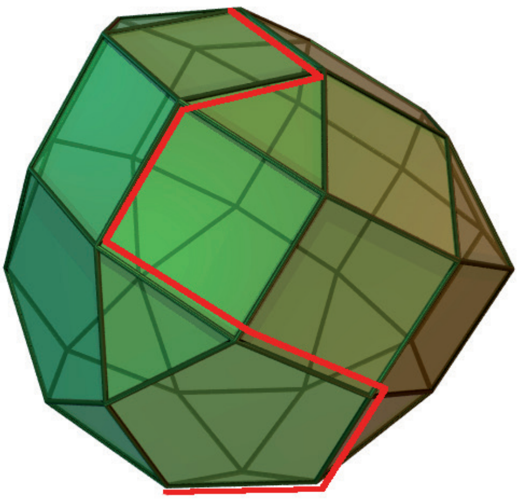


Context

Common trajectory constraints are limits on range, velocity and acceleration. Demanding trajectories to be constrained everywhere on a certain interval is a non-linear constraint that does not have an explicit form. By sampling the interval, the constraints become linear. We would like to investigate solutions that do not involve sampling/linearizing.

Constraint pruning eliminates constraints from a set of linear inequality constraints that are redundant. Sioux Mathware currently has a brute force method. The student is to implement more efficient pruning algorithms. Approximate constraint pruning removes constraints that are not redundant, but not very important either.

Model predictive control is a optimal control technique, e.g. minimizing tracking errors. The internal optimization problem is commonly a QP. State-of-the-art embedded solvers like HPIPM do not support rate constraints on the actuation natively. The student is to investigate if faster solver times are possible by implementing such constraints (and other structures) through a custom interior point method.



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REINFORCEMENT LEARNING FOR CONTROL

Assignment

Complex controllers can be implemented through deep neural networks that are trained using reinforcement learning (RL). Such a system is self-learning through interaction with an environment. Since RL techniques are data-intensive and learning by interacting with a real-world environment is often not possible, virtual environments are typically used for training the controller. Recent research shows that learning from pixels can be as efficient as from state-based features in case the state is observable from the pixels.
You will use game/physics/rendering engines to train a controller using reinforcement learning. As a specific case, we initially focus on balancing a ball on a platform. We possess such a platform as a physical system at Sioux.

Internship overview

- Master Student
- Internship (potentially Graduation)
- Mathware
- Location: Eindhoven

Technologies

- Reinforcement Learning
- Control
- Simulation
- 3D/Game Engines (Unity)

Activities

You will investigate simulation tools for RL purposes, in particular Unity and will setup an environment for simulation and training. You will consider various RL algorithms and test a selection of these. You probably need to tweak the training and model so it works.

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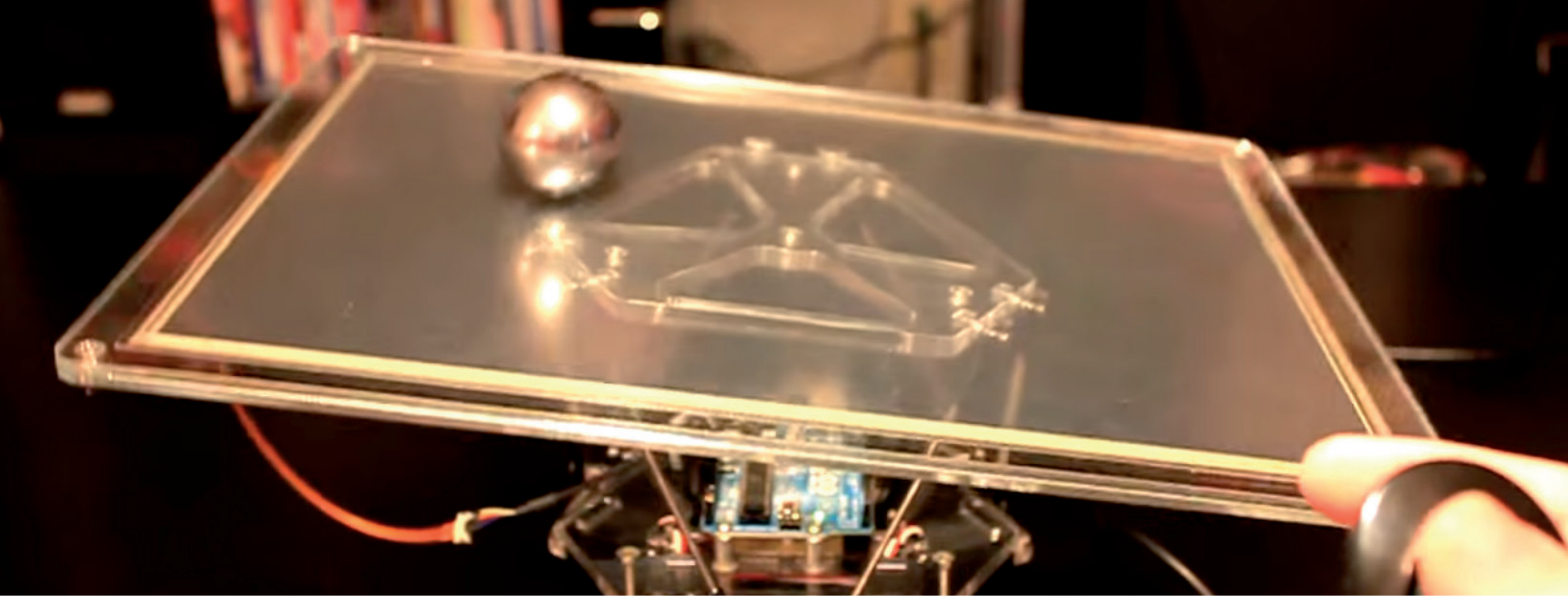
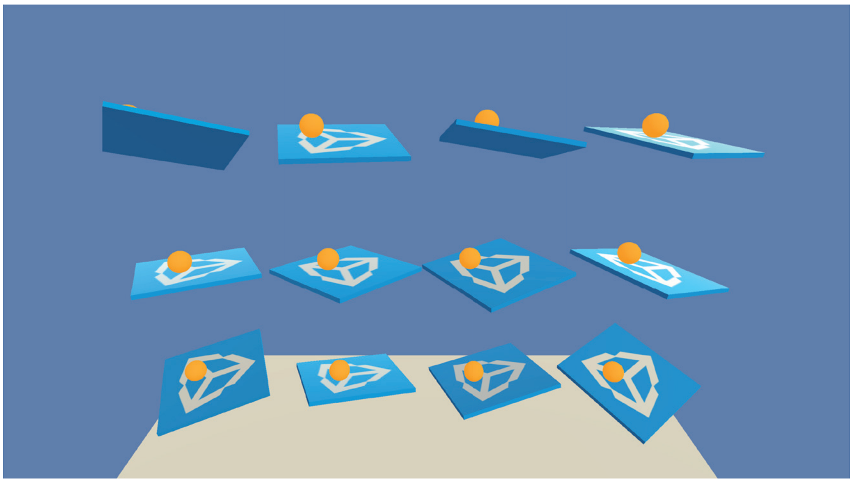


Context

The sim-to-real gap is about learned policies in a virtual environment failing in the real world. How to make it work in a real environment too? If time allows, you could also investigate how to transfer a learned policy in a virtual environment to a real physical system.



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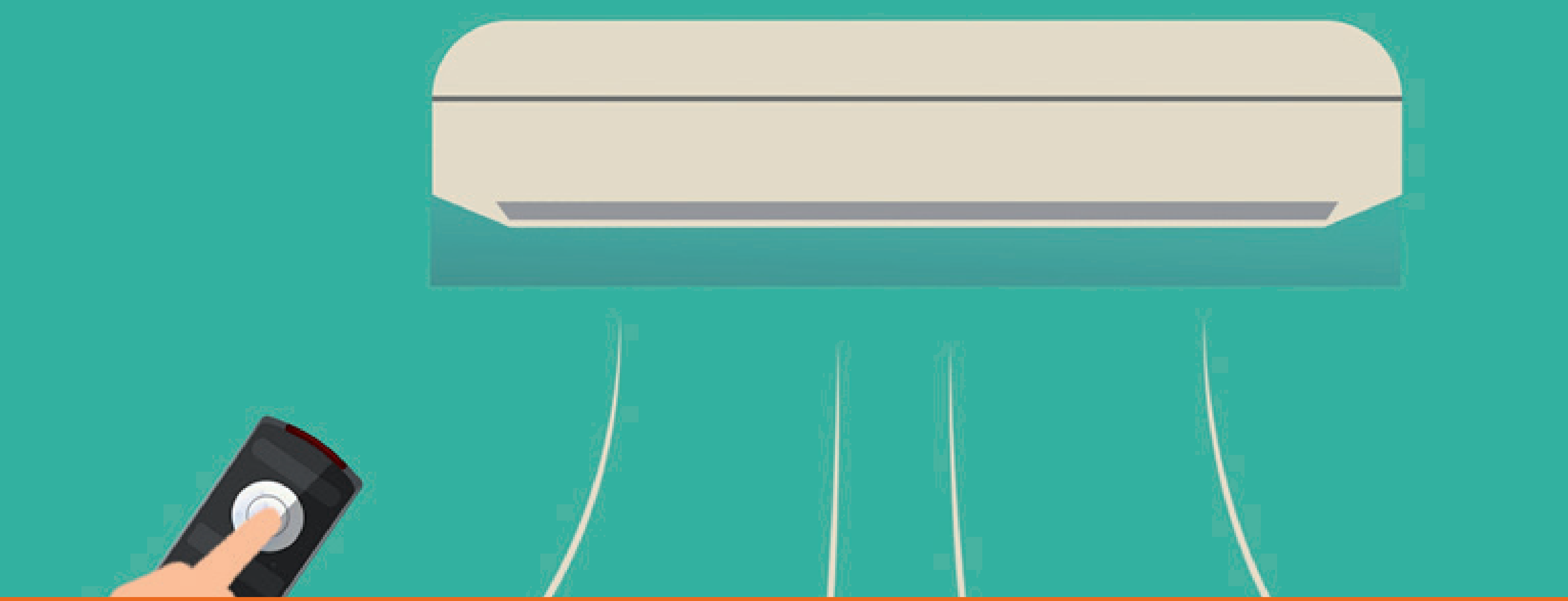

THERMAL COMFORT OPTIMIZATION

Assignment

The goal of this project is to simulate the air circulation and temperature profile in a room over time for different setups of isolation, ventilation and temperature control (heating and cooling). This is done by making a CFD simulation. Because running CFD simulations is expensive, a reduced order model (ROM) can be made based on the CFD simulation to quickly investigate new setups. The idea is to find an optimal setup which keeps the room in a specified temperature range, while also being energy efficient. Because of the time-dependent outdoor temperature, one needs to apply uncertainty quantification techniques in the optimization. A suitable way to do so is to build a parametric representation of the data and use clustering to select suitable 24h-scenarios.

Internship overview

- Master Student
- Graduation
- Mathware
- Location: Eindhoven

Technologies

- Computational Fluid Dynamics
- Model Order Reduction
- Uncertainly Quantification

Activities

The project starts by making a 2D CFD simulation which is extended to 3D. The options for isolation, ventilation and temperature control are modelled next, followed by the computation of temperature scenarios. Then, one can combine the simulation with the scenarios into a reduced model, which is used for optimization.

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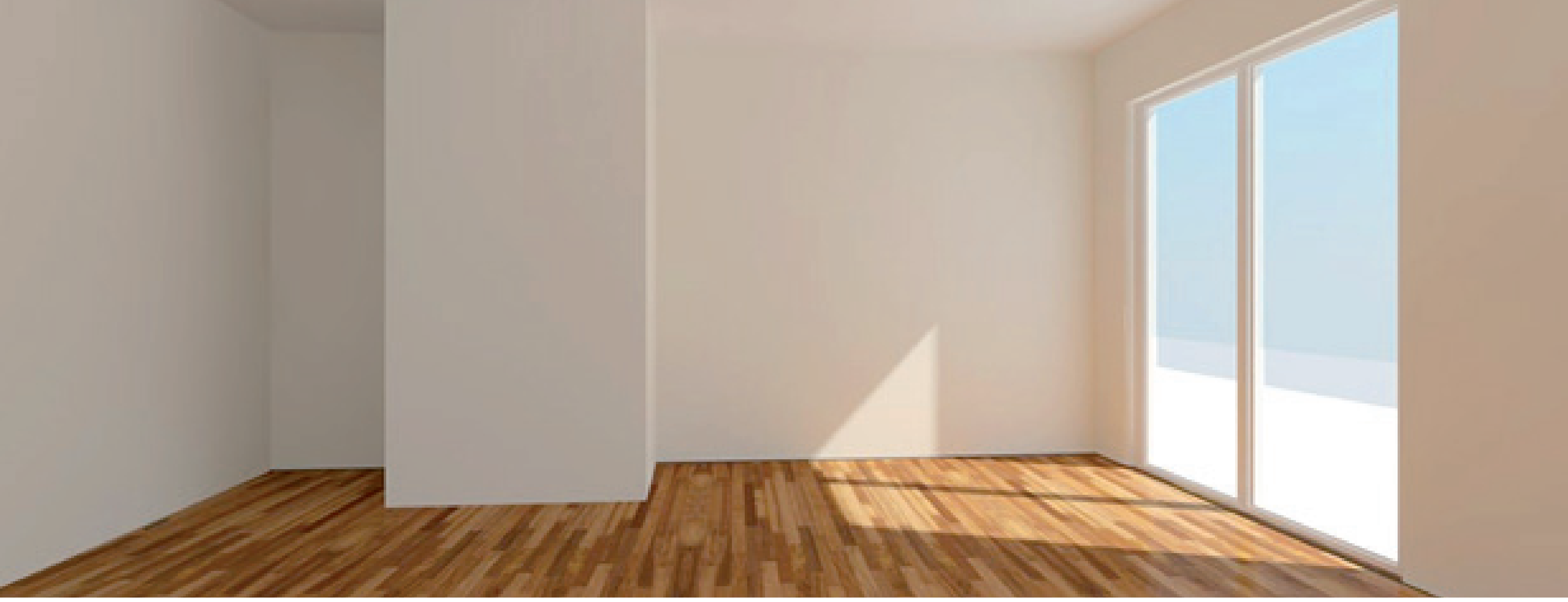
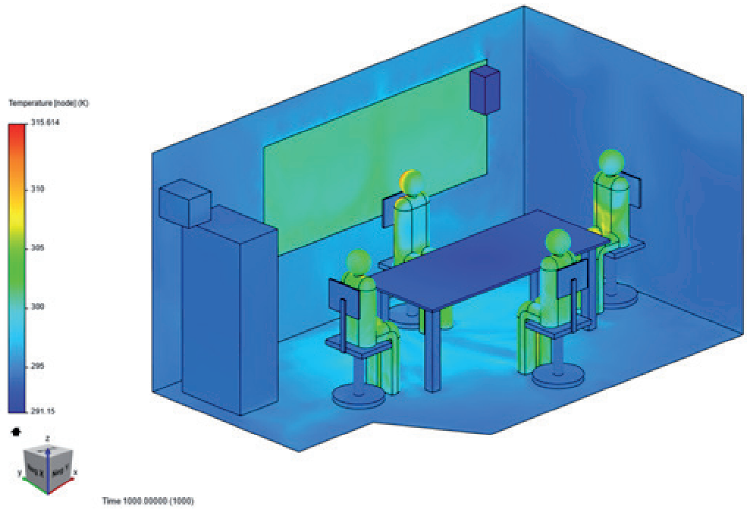


Context

For historical reasons, buildings in the Netherlands have been built to capture as much heat as possible due to cold winters and mild summers. With climate change leading to longer, hotter summers with less cooling during the nights, this can lead to overheated rooms. Isolation is a solution which helps to keep houses warm during winters and cold during summers. However, too much isolation can have an unwanted effect on the air quality inside when the ventilation is insufficient, or improperly adjusted for temperature differences. A reduced air quality can lead to health issues and needs to be avoided.



Why choose Sioux?

- Working on innovative technology
- Challenging, dynamic and varied work
- A comfortable and personal work environment
- Plenty of opportunities for personal development
- Great carreer opportunities
- Contributing to a safe, healthy and sustainable society

Get in touch!
Would you like to know more about this student assignment?

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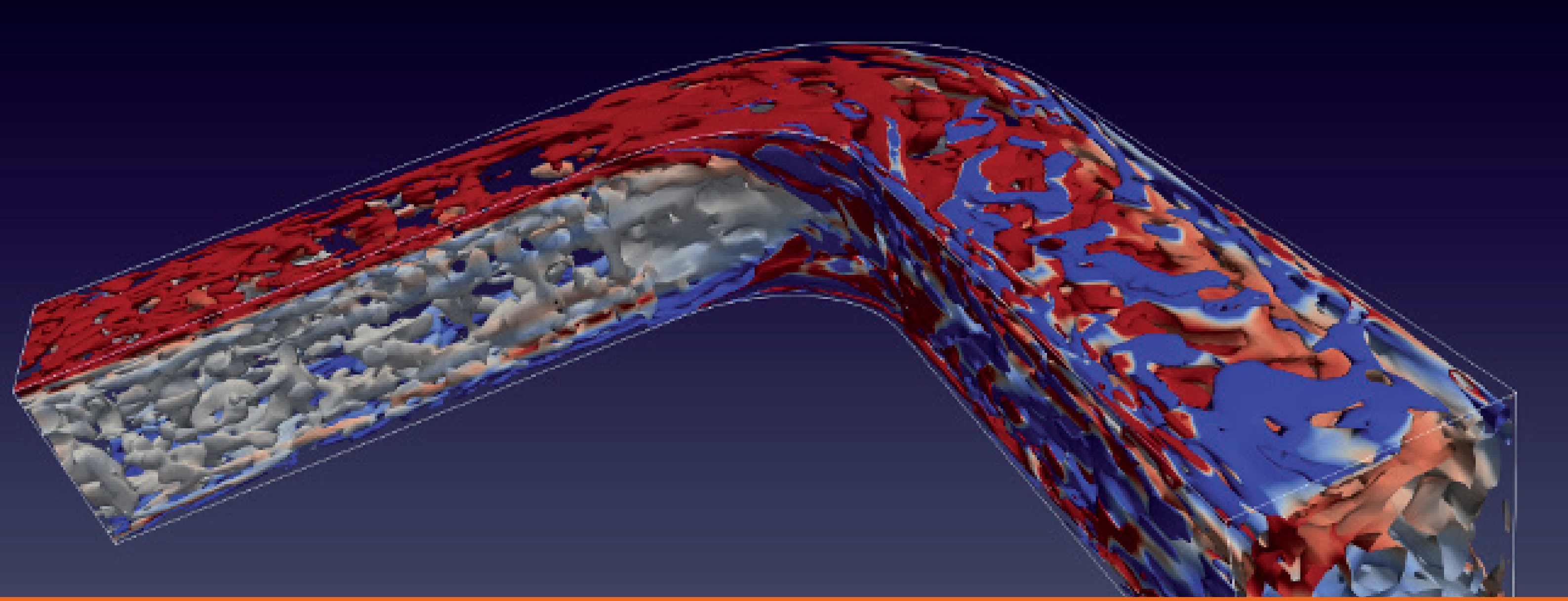

MACHINE LEARNING FOR TURBULENT FLOWS

Assignment

Computational Fluid Dynamics (CFD) simulations can be very challenging, especially when the flow becomes turbulent. Standard turbulence models used in commercial CFD packages are known to be inaccurate in many complex real-world applications. In this project, we explore the possibilities to improve turbulence models using machine learning techniques. The main question is if machine learning provides more accurate results than a state-of-the-art CFD model. For this purpose, we implement a turbulence model in a machine learning framework and use data from high-fidelity simulations (e.g. Large-Eddy Simulations, LES) as ground truth and for quantitative comparison. Specifically, we investigate the ability of the model to qualitatively capture complex flow features in various geometries. Furthermore, a practical (robust and fast) implementation in a CFD code should be developed.

Activities

- Generate training data by setting up and running LES in OpenFOAM for various geometries
- Obtain a turbulence model by training a neural network (or equivalent machine-learning algorithm
- Implement the new model in OpenFOAM
- Extend the turbulence model by adding features (geometry dependence, pressure gradient, heat transport)

Internship overview

- Master Student
- Graduation Assignment
- Mathware
- Location: Eindhoven

Technologies

- Computational Fluid Dynamics
- Machine learning
- Large-Eddy Simulations
- Data Analysis

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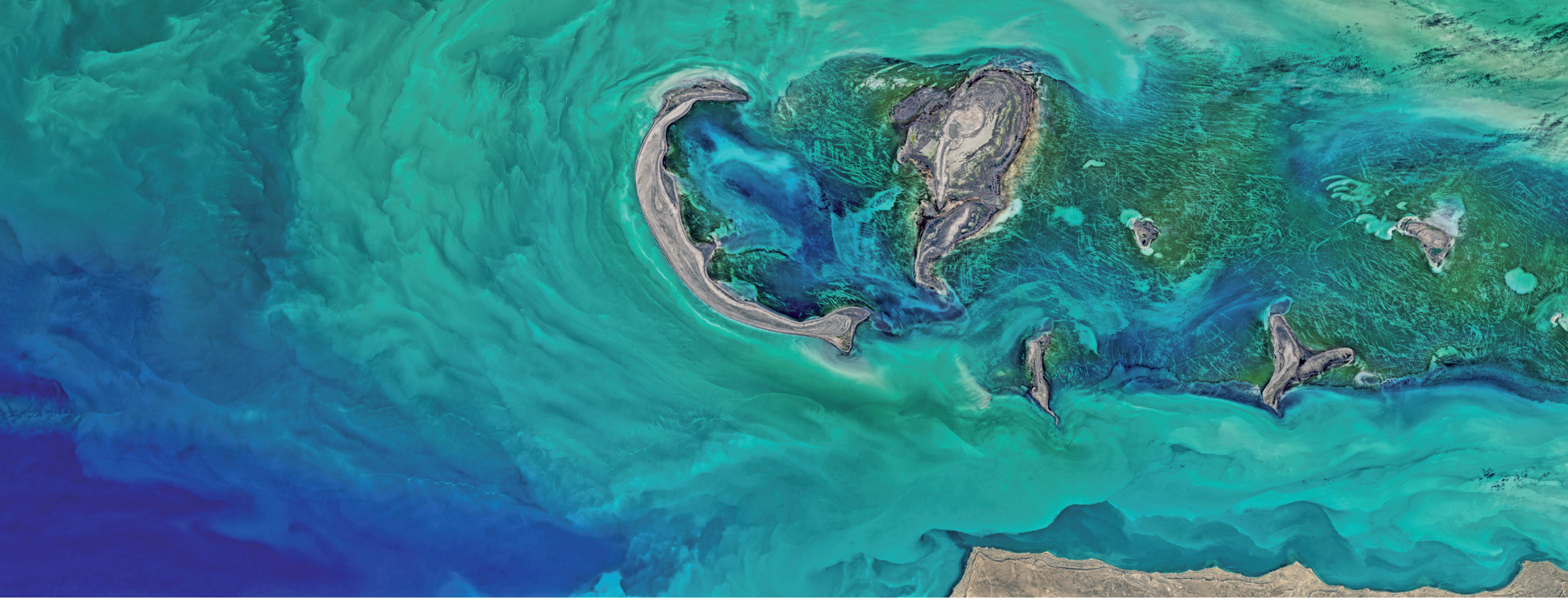

Context

For many high-tech companies, computational physics simulations are a useful tool for product design and prototyping. At Sioux Mathware we often work with commercial packages like Comsol to perform such simulations for clients. These simulations can be very challenging, especially when fluid flow is involved. For high Reynolds numbers, such flows can become turbulent and difficult to model. Despite being a very old research topic, the "perfect" turbulence model has never been found, and the standard models used in commercial CFD packages are known to be inaccurate.

However, since a few years turbulence research has turned towards machine learning to improve existing turbulence models. The general idea is that a machine-learning algorithm (e.g. neural networks, random forests) can be trained on data from high-resolution simulations and experiments to "learn" a more advanced functional relationship between the turbulence and the mean-flow quantities.

At Sioux Mathware we have explored this topic in previous research/student projects and wish to bring this to the next level. The goal is a practical implementation that can be used in commercial projects. Crucial open questions that remain:

1) on how many different geometries do we need to train to capture complex flow features?
2) which features / physics can be included in the model to further improve it?

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