Master thesis topic

February - July 2027

MASTER THESIS TOPIC

3D-Aware Self-Improving AI for High-Precision Close-Range Photogrammetry

Introduction

At CERN, the European Organization for Nuclear Research, physicists and engineers are probing the fundamental structure of the universe. Using the world's largest and most complex scientific instruments, they study the basic constituents of matter - fundamental particles that are made to collide together at close to the speed of light. The process gives physicists clues about how particles interact and provides insights into the fundamental laws of nature. Find out more on http://home.cern.

Join the Geodetic Metrology group at CERN, where you will take part in the metrology and alignment of the wide variety of components that are used in particle accelerators and detectors. You will be using, developing or testing state-of-the art surveying tools and software to achieve the sub-millimetre accuracy necessary to achieve our goals. Take part!

Diversity has been an integral part of CERN's mission since its foundation and is an established value of the Organization.

Master subject topic and objectives:

Context:

CERN's Geodetic Metrology (GM) group uses close-range photogrammetry to measure the position of accelerator or detector components with very high precision, down to a few micrometres.

A previous internship (a proof of concept) recently showed that a deep-learning network can measure coded photogrammetric targets with the required sub-pixel precision. This was tested using EMAPS (see this paper), an existing measurement system, mainly as a convenient real data source.

The GM group now wants to go one step further: build a more general method, not tied to EMAPS or to any specific instrument, that can be used for high-precision close-range photogrammetry in general.

Objective:

Every precise photogrammetric measurement is redundant by nature as the same point is measured in several images. Combining these observations in a bundle adjustment calculates 3D positions, together with a small residual error for each observation.

Today, this 3D coordinate is only computed after the 2D measurement, is never used to improve the neural network itself.

The goal of this internship is to design a training method where the network learns to measure targets more precisely by using this 3D information, in addition to (or instead of) classical supervised learning.

To keep things concrete, the student will start with standard coded targets, using existing EMAPS images as a convenient dataset. The training method itself must stay general, independent of EMAPS.

Proposed Work:

The work is organized in four steps:

1. **Baseline and Current Pipeline:**
    - Learn how the current pipeline measures coded targets: detection, sub-pixel measurement, and bundle adjustment. Reproduce its current precision as a baseline.
    - Study the redundancy already present in these measurements (multiple lines of sight per target) and how the bundle adjustment uses it.
2. **3D-Consistency Training Architecture:**
    - Build a differentiable link between the network's 2D predictions and a 3D triangulation / bundle adjustment step, so that 2D residuals can be used to train the network.
    - Choose a loss function (e.g. sum of squared residuals) and add safety mechanisms against divergence: for example, anchor the network to the classical supervised result and relax this anchor step by step while closely monitoring the training.
3. **Verification and Comparison:**
    - Test the method step by step: first on simple, simulated data, then on real acquisitions.
    - Compare accuracy, reliability, and network stability with the classical analytical method and with the existing supervised network.
4. **Generalization (end of internship, if time allows):**
    - If the previous steps work well, try applying the same method to other target or feature types (e.g. spheres, wire, QR-codes etc.).

Qualifications:

Eligibility criteria:

- You are in your 5th year of master's degree.
- You are a full-time student and will remain a full-time registered student throughout the internship at CERN
- You have good working proficiency in English and/or French.

Skills and/or knowledge:

- Strong programming skills in Python, ideally with a deep learning framework (PyTorch, TensorFlow).
- Knowledge of computer vision and deep learning (CNNs, object detection, keypoint/landmark regression).
- Basics of photogrammetry and multi-view geometry (camera calibration, triangulation, bundle/least squares adjustment).
- Rigorous, curiosity, and interest for applied research.

ADDITIONAL INFORMATION

What we offer:

- An internship contract for a duration of between 4-6 months.
- A monthly allowance of 1,593 Swiss Francs.
- One of CERN's key missions is education. Our experts enjoy sharing knowledge with committed and passionate students.

How to apply:

You will need the following documents to complete your application:

- A CV in English or French (in a PDF format).
- **Apply for the short-term internship by 15th October 23:59 here:** https://smrtr.io/BL_ZM and inform be-gm-secretariat@cern.ch and florian.barcet@cern.ch of your application.

Further info and contacts:

In case of questions, please contact: Dirk Mergelkuhl: Dirk.Mergelkuhl@cern.ch (Section Leader)

- Some info about the group: https://be-dep-gm.web.cern.ch/ and https://espace.cern.ch/SU/default.aspxh
- Some further info about our activities: https://videos.cern.ch/record/2718427, https://videos.cern.ch/record/2298440

Master thesis topic

6 months in 2027

MASTER THESIS TOPIC

Evaluation and Automation of Wire Offset Measurement using the ATS800

Introduction

At CERN, the European Organization for Nuclear Research, physicists and engineers are probing the fundamental structure of the universe. Using the world's largest and most complex scientific instruments, they study the basic constituents of matter - fundamental particles that are made to collide together at close to the speed of light. The process gives physicists clues about how particles interact and provides insights into the fundamental laws of nature. Find out more on http://home.cern.

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Master subject topic and objectives:

The Future Projects (FP) section within the Geodetic Metrology (GM) group is responsible for developing the alignment concept and strategy for the Future Circular Collider (FCC). The collider's components are subject to extremely stringent alignment requirements to ensure the smooth and efficient transport of particle beams. Tens of thousands of components will need to be positioned and aligned within very tight tolerances. This will require the measurement workflow to be automated and optimized as much as possible.
A combination of polar 3D observations performed with a laser tracker and wire-offset measurements has been identified as a promising measurement strategy for meeting these requirements. Currently this combination of measurement techniques requires two separate instruments and two distinct workflows. The new ATS800 laser tracker may offer a potential solution by enabling both types of measurements with a single instrument, particularly due to its ability to scan wires with high precision. The objective of this project is to assess the precision and accuracy of wire-offset measurements performed with the ATS800. The project will also involve developing and optimizing a suitable measurement workflow.

You will have several objectives, building on the support of your supervisor and the expertise available in the GM group:

- Become familiar with the ATS800 and with wire offset measurement principle.
- Understand and analyze the current challenges associated with scanning wires using the ATS800.
- Assess the precision and accuracy of the proposed method by comparing it with the current manual and photogrammetric methods.
- Improved the ATS800 wire-scanning process by developing software enhancements and testing multiple hardware solutions, increasing ease of use and reliability.
- Define and validate a wire-scanning workflow using the ATS800.

Qualifications:

Eligibility criteria:

- You are in your 5th year of master's degree.
- You are a full-time student and will maintain your full-time registration throughout the internship at CERN.
- You have good working proficiency in English and/or French.

Skills and/or knowledge:

- Theoretical and practical experience using least square-based algorithm.
- Proficiency in programming languages such as Python.
- Rigorous and methodological scientific approach to problem solving.
- Interest in high-precision measurement.
- Strong attention to detail and a curious mindset.
- Knowledge and experience in image processing and/or automated point-cloud processing would be a plus.

ADDITIONAL INFORMATION

What we offer:

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Further info and contacts:

- In case of questions, please contact:
  - Vincent Gerligand: vincent.gerligand@cern.ch (Supervisor)
  - Dirk Mergelkuhl: dirk.mergelkuhl@cern.ch (Section Leader)
- Some information about the group: HERE.
- Some further information about our activities: Video_surveyor at CERN, Video_Alignment systems

Master thesis topic

February - July 2027

MASTER THESIS TOPIC

Towards a Portable Calibration Bench for High-Precision Inclinometers

Introduction

At CERN, the European Organization for Nuclear Research, physicists and engineers are probing the fundamental structure of the universe. Using the world's largest and most complex scientific instruments, they study the basic constituents of matter - fundamental particles that are made to collide together at close to the speed of light. The process gives physicists clues about how particles interact and provides insights into the fundamental laws of nature. Find out more on http://home.cern.

Join the Geodetic Metrology group at CERN, where you will take part in the metrology and alignment of the wide variety of components that are used in particle accelerators and detectors. You will have access to the existing calibration bench, laser tracker, and a reference inclinometer, as well as a multidisciplinary team able to provide support in mechanical and electrical engineering. Take part!

Diversity has been an integral part of CERN's mission since its foundation and is an established value of the Organization.

Master subject topic and objectives:

Context:

CERN (the European Organization for Nuclear Research) is the world's largest physics laboratory. Its primary objective is to study the fundamental laws of the universe. CERN's surveyors are responsible for positioning

particle accelerator and detector components to sub-millimetre precision, including those of the Large Hadron Collider (LHC).

The High-Luminosity LHC (HL-LHC) project aims to enhance the performance of the LHC and maximise its potential for scientific discovery. In terms of alignment, this requires stricter tolerances, which will be achieved using the Full Remote Alignment System (FRAS).

As part of the FRAS project, new measurement devices and sensors have been developed to meet accuracy, safety and environmental requirements. Inclinometers (tilt sensors), with a resolution of approximately 10 microradian, will be deployed for the real-time monitoring of the roll angle of the accelerator components. Unlike optical alternatives, each of these sensors must be individually calibrated in the field before installation on the accelerator components.

Objective:

The HL-LHC project will require the deployment of a significant number of high-precision capacitive inclinometers for the alignment and monitoring of accelerator components. Each sensor must be individually calibrated to accurately determine the relationship between its digital output and the corresponding inclination angle, using a repeatable and well-characterised calibration procedure.
A key constraint is that calibration must be performed using a portable test bench, allowing sensors to be calibrated close to their installation location and shortly before integration. This requires dedicated software combining measurement acquisition, data processing, determination of calibration parameters, and assessment of calibration quality.
The objective of this Master's thesis is to develop, implement, and validate the methodology and software required for this portable calibration system. The work will include experimental characterisation of the sensors and existing calibration setup, development of suitable data-processing and parameter-estimation algorithms, and their integration into the existing CERN control software framework.
Finally, the complete calibration procedure will be experimentally validated. Its repeatability and accuracy will be assessed, the principal sources of uncertainty identified, and an overall calibration uncertainty budget established to verify compliance with the HL-LHC measurement requirements.

Proposed Work:

- Become familiar with the capacitive inclinometers, existing calibration bench, reference instrumentation, and calibration requirements.
- Perform experimental calibrations to characterise sensor response, repeatability, measurement noise, and the main sources of error.
- Develop and validate the calibration methodology, including data filtering, outlier rejection, least-squares parameter estimation, and calibration quality assessment.
- Contribute to the preparation, commissioning, and documentation of a portable calibration bench, considering portability, repeatability, calibration time, and cost efficiency.
- Implement the calibration algorithms and automated measurement procedure within the existing CERN software control framework.
- Validate the complete calibration system experimentally, assess its repeatability and accuracy, establish the calibration uncertainty budget, and compare the achieved performance with HL-LHC requirements.

Qualifications:

Eligibility criteria:

- You are in your 5th year of master's degree.
- You are a full-time student and will remain a full-time registered student throughout the internship at CERN.
- You have good working proficiency in English and/or French.

Skills and/or knowledge:

- Strong programming skills in Python.
- Knowledge of data analysis and least-squares adjustment methods.
- Knowledge of data acquisition, control systems, and sensor instrumentation would be an asset.
- Rigorous and methodical approach, curiosity, and a strong interest in applied research.

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Further info and contacts:

In case of questions, please contact: Mateusz Sosin: mateusz.sosin@cern.ch (HPA Section Leader).

- Some info about the group: https://be-dep-gm.web.cern.ch/
- Some further info about our activities: https://videos.cern.ch/record/2718427, https://videos.cern.ch/record/2298440