Gathered projects for the FIT CTU Cooperation with Industry program

Homotopy continuation method for solving systems of nonlinear equations

Description

Systems of nonlinear equations often arise in real-world problems and applications in areas such as physics, chemistry, economics or robotics. It is therefore one of the most important challenges in numerical computation with great practical value.

Homotopy continuation method is an alternative to Newton-based methods, which are often used in practice. In cases that are difficult for Newton-based algorithms which often arise in practice, the continuation algorithm is more likely to find a solution. The idea is that instead of dealing with the original problem directly, it is started with some “easy” system of equations for which the solution is obvious. It then gradually transforms the easy system into the original system, and follows the solution as it moves from the solution of the easy problem to the solution of the original problem. Although the core idea is quite simple, making the algorithm practical requires use of interesting mathematical techniques and numerical tricks.

This assignment utilises knowledge from Mathematical Analysis and Linear Algebra, and good understanding of their basics is necessary for successful completion.

Goals

- Study the method as described in provided references. No need for deep understanding of the mathematical details, just to the level required for the implementation.
- Implement the method in the Rust programming language with libraries predefined by Datamole s.r.o.
- Evaluate the implementation on standard benchmarks, benchmarks from [5] and datasets provided by Datamole s.r.o. Compare the method with the trust-region algorithm implemented in gomez library.

Technologies

Rust

Rough time estimate

Total: ~120 hours

Reward

30 000 CZK

References

[1] Jorge Nocedal, Stephen J. Wright: Numerical Optimization (2006)

[2] Tianran Chen, Tien-Yien Li: Homotopy continuation method for solving systems of nonlinear and polynomial equations (2015)

[3] Eugene L. Allgower, Kurt Georg: Introduction to numerical continuation methods (2003)
[4] Layne T. Watson: Globally convergent homotopy methods: A tutorial (1989)
[5] Layne T. Watson, Stephen C. Billups, Alexander P. Morgan: Algorithm 652: HOMPACK: A Suite of Codes for Globally Convergent Homotopy Algorithms (1987)

Required knowledge

Mandatory
Linear Algebra 1
Mathematical Analysis 2

Recommended
Linear Algebra 1
Mathematics for Informatics
Nonlinear Continuous Optimization and Numerical Methods
Selected Topics in Optimization and Numerical mathematics

Mentor: Ing. Petr Nevyhoštěný

Detection of 3D printing failures by close range 3D camera or LIDAR

Description

3D printing is an innovative additive manufacturing technology that is applicable in a wide range of use cases such as prototyping, small batch manufacturing or producing masters for mould making. The rise of affordable 3D printers and a large selection of 3D printing materials make 3D printing available for home and workshop usage.

The success of printing a model on a 3D printer is however highly dependent on the preparation of the model by the operator of the 3D printer, printing settings and correct calibration of the 3D printer. Issues in any of those variables can cause 3D printing defects or complete failures, causing wasted time, energy and material and potentially also risking damage to printer components.

The task is to build a prototype of a system that will monitor progress of a 3D print by a 3D camera and alert the operator and/or pause the 3D print in case a failure in the print is detected. The monitoring system will detect failures by comparing output from the 3D camera to the expected state of the 3D print defined by the printed object model and sliced toolpath. The system will also have metadata about the current state of the print (current Z height, printing progress percentage) available to improve the accuracy and reliability of the detection.

Because of the complexity of the whole project, it is separated into 3 consecutive stages.

Goals - Phase 1 - Fault data collection and annotation

- Setup the 3D printer with required hardware (connected computer, 3D camera) and software (Octopi, camera SDK, ...).
- Determine the best way to monitor the print progress with the supplied 3D camera (angle and distance of the camera, mounting to the printer).
- Design and implement software for data collection.
  Data that should be recorded:
  - 3D camera point clouds with attached G-code line progress for each layer.
  - Complete printed G-code and slicing parameters.
  - Sliced model (as stl) with known sliced orientation.
- Simulate and record different types of 3D print failures and issues.
- Annotate the recorded dataset with timestamps when the faults happened and type of the fault present.

Goals - Phase 2 - Fault detection model development

- Research and experiment with different approaches on how to compare recorded outputs of the 3D camera (sparse point clouds) to the associated data about the 3D printed model (sliced G-code and progress information, triangulated STL model).
- Develop a model that will detect deviation from the expected print state and the type of the fault based on the data available.
- Validate and test the model on the data collected in the previous phase of the project.

Goals - Phase 3 - Fault detection model deployment and testing

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- Deploy the model developed in phase 2 to the embedded system attached to the printer.
- Extend the recording solution from phase 1 to evaluate the model continuously and monitor its outputs during a running 3D print. The system should be able to pause the running print automatically and alert the user in case a fault is detected.
- Perform end to end testing of the whole system to find its strengths and shortcomings.

Rough time estimate
Phase 1 - 140 hours
Phase 2 - 110 hours
Phase 3 - 90 hours

Reward
Phase 1 - 35 000 CZK
Phase 2 - 27 500 CZK
Phase 3 - 22 500 CZK

Mentor
Bc. Tibor Szolár

Please be aware that the project is divided into three sequential stages, and the applicant is currently applying for the initial stage. We prefer candidates interested in fulfilling consecutive projects.