UNSAT-*Pi* - A miniaturised test apparatus for examining the uniaxial compressive strength of partially saturated granular media during CT imaging

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Repository including the design for a measurement device for the uniaxial compressive strength controlled via a Raspberry Pi single-board computer, named the "UNSAT-*Pi*", which can be placed in a micro-CT chamber for *in situ* CT experiments.

The set-up was developed and used by the authors to study the uniaxial compressive strength of unsaturated granular soils by means of X-ray computed tomography, *e. g.*, see Milatz (2021)[1].

The published files will not be updated on a regular basis and no further warranty is given. Users are requested to test the functionality of their applications thoroughly.

Based on Milatz (2019)[2] and Milatz (2020)[3] the set-up for the UNSAT-*Pi* was modified in the framework of project 401096010 [4] funded by the German Research Foundation (Deutsche Forschungsgemeinschaft, DFG).

The repository is structured as follows:

1. CAD construction files
2. Datasheets
3. Wiring scheme
4. Python userscript
5. Example measurement and evaluation

1. CAD construction files

This folder contains the construction files (.ipt/.dwg and .pdf file format) for building the proposed apparatus.

0. UnsatPi.iam (Assembly File)
1. MountingAdapter
2. SensorBaseplate
3. AcrylicCylinder
4. StepperMotorModification

[1]Milatz, M.; Hüsener, N.; Andò, E.; Viggiani, G.; Grabe, J. (2021): Quantitative 3D imaging of partially saturated granular materials under uniaxial compression. In: *Acta Geotech. (16), S. 3573–3600.* DOI: 10.1007/s11440-021-01315-5.

[2]Milatz, M. (2019): Zur Anwendung von Einplatinen-Computern in der bodenmechanischen Forschung und Lehre am Beispiel eines einaxialen Druckversuchs zur Untersuchung teilgesättigter, granularer Böden. In: *geotechnik 42 (1), S. 21–33.* doi: 10.1002/gete.201800015

[3]Milatz, M. (2020): Application of single-board computers in experimental research on unsaturated soils. In: *E3S Web Conf. 195, S. 2022.* doi: 10.1051/e3sconf/202019502022

[4]DFG-Project 401096010: "Microscale investigations of the hydro-mechanical behaviour of unsaturated granular soils with computed tomography" Link: https://gepris.dfg.de/gepris/projekt/401096010

[5]Heinrich, D.; Milatz, M. (2022): UNSAT-*Pi* - A miniaturised test apparatus for examining the uniaxial compressive strength of partially saturated granular media during CT imaging. doi: https://doi.org/10.15480/336.4393

5. LoadingPiston
6. StandOff StepperMotor
7. StepperMotor MountingPlate
8. MountingPin LoadingPlate
9. SpecimenPlatform
10. ShaftCoupling
11. Sensor (files can be downloaded from manufacturer website)

Small parts such as screws and hoses must be purchased separately.

2. Wiring Scheme

The wiring scheme of the electronical parts can be taken from two files:

- unsatpi_wiring_scheme.pdf
- unsatpi_wiring_scheme.fzz

The latter is given in the "Fritzing" file format. fritzing [6] is an open-source hardware initiative, that published a software, where wiring schemes can be visualized in a simple and intuitive way.

3. Datasheets

This folder contains the datasheets for the electrical parts of the set-up. This assembly consists of

- an S-shape load cell of type KD34s developed by "ME- Meßsysteme GmbH" with a measuring range of either ± 1 N or ± 2 N,
- a corresponding GSV-1L single channel amplifier (also "ME- Meßsysteme GmbH") which connects to
- an Adafruit ads1115 16-Bit Analogue to Digital Converter (ADC).
- The loading piston is driven by a Nema 17 stepper motor of type 17HS13-0404S.
- The stepper motor itself is driven by a DRV8825 driver board (various manufacturers).

Furthermore, a real-time clock (RTC) of type DS3231 is added to the circuit to get correct time stamps, which is totally optional.

4. Userscript - Controlling the UNSAT-*Pi*

This folder contains the main python-script for controlling the UNSAT-*Pi*

- unsatpi_userscript.py

The Userscript (unsatpi_userscript.py), being the main file, is written in Python and needs to be executed directly on the Raspberry Pi. After execution, the script will guide the user through the process of defining the needed measurement parameters.

Basically, the function unsatpi() will be executed, where all other functions are called. There are also a couple of help functions integrated in the script. Feel free to check, use or ignore them.

In a first prompt, you choose a filename for the experiment. In further prompts you are asked to set the microstepping mode of the motor and the shear rate as well as the shear distance. Important note: Keep in mind that stepper motors are supposed to be used at fairly low rotation speeds (or to be more precise: The time/delay between two (Micro)steps should not be too low). Giving values leading to low delay values will lead to an unreliable speed of the stepper motor and thus missing the set value as the software cannot keep track of the incoming data anymore. It is highly recommended to test the setup for the consistency of speeds. To optimize the runtime of the script, the measurement data is written in batches. The batch size (save_interval) is definded in line 124 of the script.

The set parameters will be written to the "*_TestInfo.txt" file. The measured data is written to the "*_data.csv" file.

[6] fritzing: https://fritzing.org/

If you're done defining all parameters, an offset measurement is performed. After finishing the offset measurement, a prompt will ask whether the experiment should be started.

5. Example measurement and evaluation

This folder contains three files:

- example_evaluation_script.py
- example_data.csv

A Python script "example_evaluation_script.py" specifically adapted to an example measurement is provided besides a file of raw measurement dataset "example_data.csv" to visualise the corresponding force measurement of an examined specimen during shearing. Here, a specimen consisting of a packing of spherical glass beads with a mean diameter of 1 mm is used.