Implementing HZDR Interactive Baseline Closure Concept Using Fuzzy Logic and Snakemake Workflows

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The poster presents an implementation of the so called Baseline Methodology which aims to address multiple challenges arising in Euler-Euler multiphase CFD simulations. The approach leverages `Snakemake` workflows for managing large set of OpenFOAM cases and Fuzzy Logic Controller for evaluating simulation results against available experimental data.

Multiphase CFD Challenges

Just for the OpenFOAM HZDR multiphase add-on[1] one could have:

- **29** drag force models
- **7** lift force models
- **4** virtual mass models

Yielding **812** potential model setups!

What is Baseline Methodology?

According to [2] it:

1. specifies a particular meta-algorithm for proposing new sub-models
2. validates them on a large number of cases
   - bubbles 1 mm - ≈15 mm
   - mostly pipe flows
   - 66 cases in total

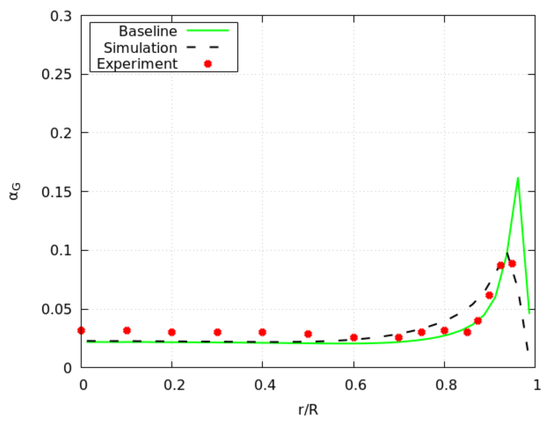

Figure 1: An example of common plot

? How to compare data on figure 1 **objectively** and **automatically**

Workflows

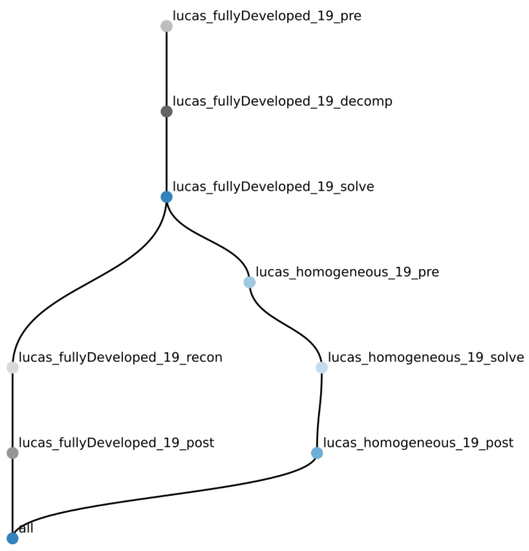

Figure 2: An example of workflow

Workflows are special structures that combine states and rules.

The `Snakemake` library is one of the many providing scripting language for designing workflows.

`Snakemake` workflow allows representing Baseline **validation cases** together with various stages of CFD simulation (more on workflows here [4]).

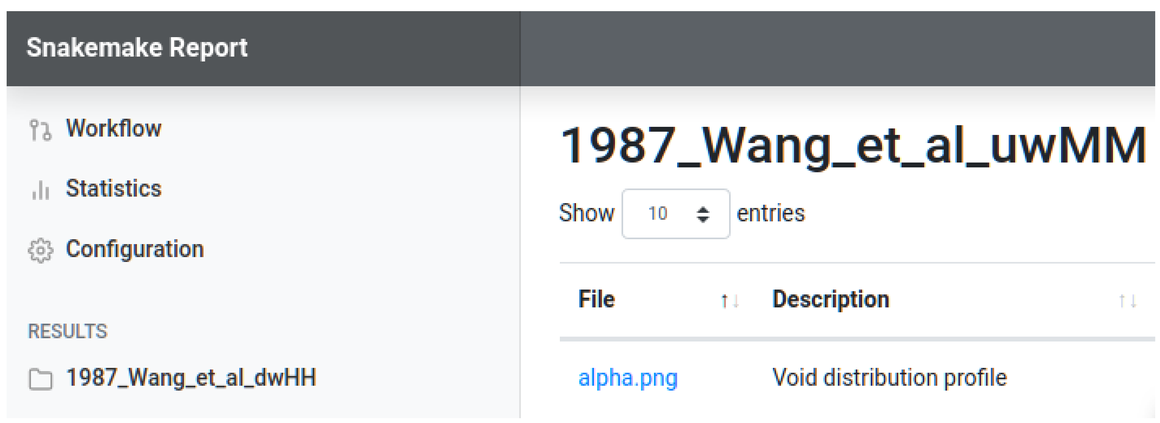

Figure 3: An example of `Snakemake` report (static HTML page with all plots embedded)

Fuzzy Logic

On the Figure 4 *Crisp Inputs*:

- **Pearson correlation coefficient**, PCC
- **Mean relative error**, MRE

Crisp Output:

- **Goodness** metric representing fitness of simulation data to experimental distributions

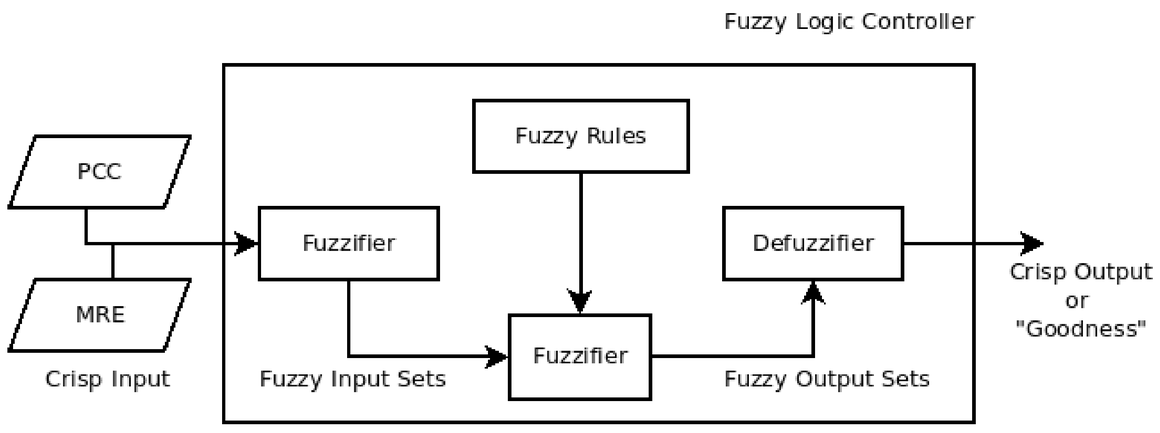

Figure 4: Schematic representation of the Fuzzy Logic Controller

On the Figure 5 example `2016_Kim_et_al_K4` from [5].

On the Figure 6 example `1987_Wang_et_al_uwMM` from [5].

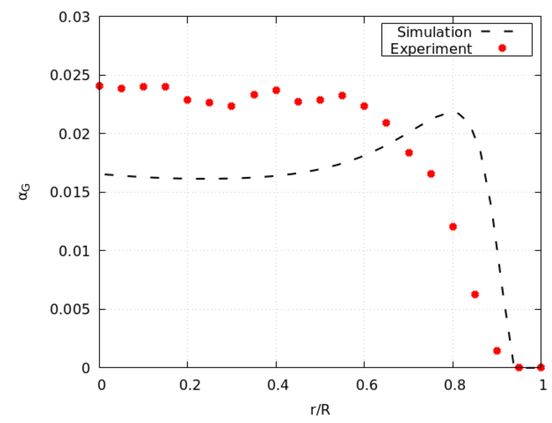

Figure 5: *Crisp Values* $PCC = 0.653$, $MRE = 0.335$, $G = 0.56$

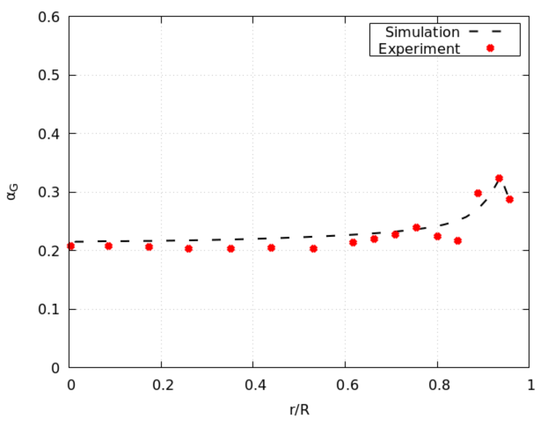

Figure 6: *Crisp Values* $PCC = 0.947$, $MRE = 0.056$, $G = 0.86$

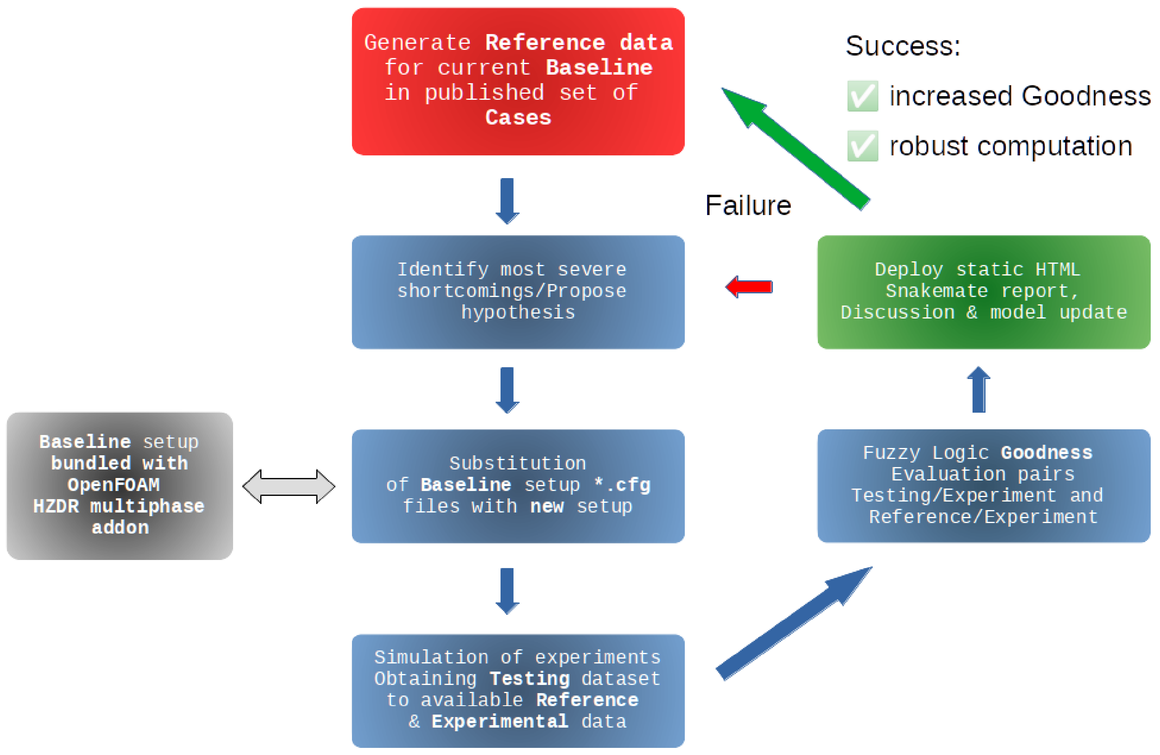

Figure 7: Baseline methodology [2] with mapped working components

[1] F. Schlegel, M. Draw, I. Evdokimov, S. Hänsch, H. Khan, R. Lehnigk, R. Meller, G. Petelin, M. Tekavčič, "HZDR Multiphase Addon for OpenFOAM", `https://rodare.hzdr.de/record/768`, 2021.

[2] Lucas, D., Rzehak, R., Krepper, E., Ziegenhein, Th., Liao, Y., Kriebitzsch, S., Apanasevich, P., 2016. A strategy for the qualification of multi-fluid approaches for nuclear reactor safety. Nucl. Eng. Des. 299, 2-11.

[3] "The Tipping Problem - The Hard Way", `https://scikit-fuzzy.readthedocs.io/en/latest/auto_examples/plot_tipping_problem.html`

[4] I. Evdokimov, S. Haensch, and F. Schlegel, "Scalable Workflows for OpenFOAM Evaluation," in IPS RAS 2020, 2020.

[5] Hänsch, Susann et al. (2021, July 1). HZDR Multiphase Case Collection for OpenFOAM (Version 2.0.0). Rodare. `http://doi.org/10.14278/rodare.1049`

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DRESDEN concept