

HSF008: GUI for Synthetic Echocardiographic EF Simulation

Harmonic Scale Framework Project

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Abstract

We present a graphical user interface (GUI) that generates synthetic left-ventricular (LV) volume time series based on a simple area-length model. The tool is designed to explore ejection fraction (EF) robustness with respect to frame rate, segmentation bias, and random noise. It produces plots, tables, and CSV exports for use in reproducibility studies. This note documents the purpose, methods, outputs, limitations, and a sample run.

1 Purpose

The GUI provides a controlled environment for simulating echocardiographic screening data. It is not a diagnostic tool but a technical framework for testing EF estimation robustness. Key aims are:

- Simulate LV geometry and motion with adjustable parameters.
- Quantify EF sensitivity to frame rate and segmentation bias.
- Provide reproducible CSV and figure outputs for method evaluation.

2 Theory (Minimal)

Ejection fraction (EF) is defined as

$$EF = \frac{EDV - ESV}{EDV} \times 100\%.$$

A synthetic LV beat is built from ellipse geometry:

$$V(t) \approx \frac{8}{3\pi} \frac{A(t)^2}{L(t)}, \quad A(t) = \pi a(t) b(t), \quad L(t) = 2 a(t).$$

The HSF element used here is only a low-order harmonic smoother (order 3) applied to suppress jitter before detecting ED/ES.

3 User Interface

The GUI has a two-column form and a splitter with plots (top) and data (bottom):

Left panel: Geometry (`a_ed`, `b_ed`, `amp_a`, `amp_b`, `phase`); timing (`hr`, `fps_ref`, `fps_list`); miscellaneous (`seed`, `out_base`).

Right panel: Bias & Noise: `area_bias_list`, ED/ES area biases (`ed_area_bias`, `es_area_bias`), ED/ES length biases (`ed_l_bias`, `es_l_bias`), and per-frame area noise SD (`area_noise_sd`).

4 Outputs

Each run produces a timestamped folder under `out_base` with:

- Figures (PNG):
 1. `lv_volume_timeseries.png` — LV volume time series with ED/ES markers.
 2. `ef_vs_fps.png` — EF versus frame rate.
 3. `ef_error_vs_area_bias.png` — EF error (pp) versus uniform area bias (%).
- CSV tables: `ef_vs_fps.csv`, `ef_error_vs_area_bias.csv`.
- A text summary in the lower pane listing baseline EDV/ESV/EF, tables, and saved files.

5 Example Run (Placeholders)

Below are placeholder axes for the three figures. Replace them with the real PNGs generated by the GUI via `\includegraphics[width=\linewidth]{path/to/figure.png}`, or leave these pgfplots stubs as schematic views.

Figure A: LV volume time series

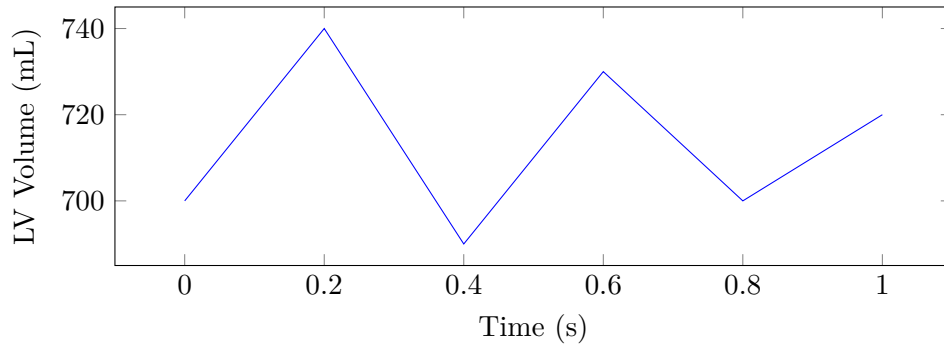


Figure B: EF versus frame rate

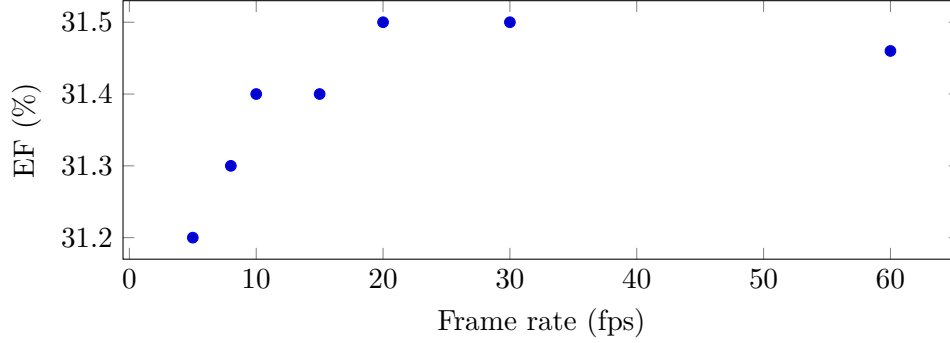
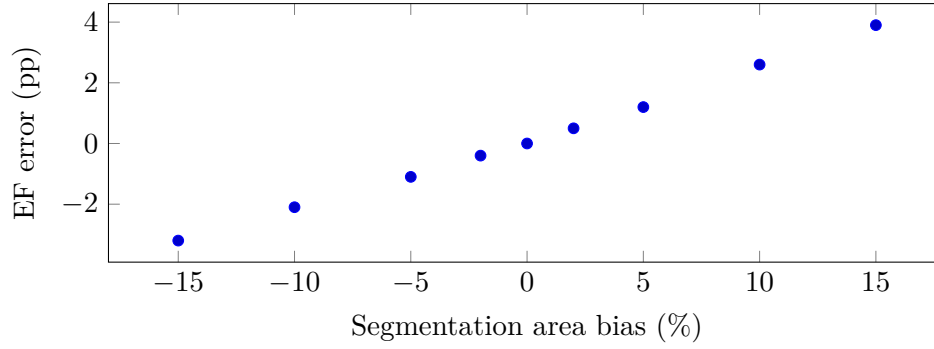


Figure C: EF error versus uniform area bias



6 Limitations

- Synthetic signals only; no clinical validation is implied.
- Single-plane area-length proxy can bias EF versus biplane Simpson's.
- “Processing success” refers to running the pipeline without errors, not to accuracy.

7 Reproducibility

- Run: `python hsf008_gui.py` (requires: Python 3, tkinter, numpy, pandas, matplotlib).
- Outputs appear under: `<out_base>/HSF008_gui_YYYYMMDD_HHMMSS/`.
- Replace the placeholder plots above with the generated PNGs for a final report.