OptiView Pro: UX/UI Handout

Linked Dual-Space Visualization for 4-Objective Pareto Fronts with ML-Driven Design Space Exploration

Final Integrated Solutio

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1 Overview & Core Design Philosophy

OptiView Pro supports decision-making in a 4-objective multi-objective optimization (MOO) problem where three objectives are continuous (f_1, f_2, f_3) and one objective is binary/discrete ($f_4 \in \{0, 1\}$). In addition, users explore the *design/feature space* before objectives: a 2D input plane (x_1, x_2) with a PyTorch binary classifier producing a probability field $P(\text{class} = 1 \mid x_1, x_2)$ and a decision boundary at 0.5.

Design principle: Linked Dual-Space Understanding. The interface connects *causes* (design space, ML predictions) to *effects* (objective space, Pareto optimality) through tightly linked views, enabling intuitive discovery and confident selection.

Pareto emphasis principle. Pareto points are always visually dominant via size/opacity/outline separation, while still grounded in the full feasible set.

Clutter control refinement. All cross-view synchronization remains on hover/selection, while *optional linking-line cues* can be toggled on/off to keep the workspace clean.

2 Data & System Context

- **Dataset A (Feasible set):** all feasible points with fields ($x_1, x_2, f_1, f_2, f_3, f_4$); potentially large.
- **Dataset B (Pareto set):** nondominated subset with the same fields.
- **ML model output:** probability grid $Z(x_1, x_2) = P(\text{class} = 1 \mid x_1, x_2)$, derived from a 2D mesh and PyTorch forward pass.

3 Primary User Goals

1. Identify Pareto-optimal solutions quickly.
2. Understand trade-offs among f_1, f_2, f_3 and how f_4 changes the front.
3. Relate feature-space regions to objective-space performance.
4. Filter, shortlist, and compare candidates for final decisions.

4 Dashboard Layout (Final)

The UI uses a split dashboard with linked panels:

- **Top-Left: Design Space (Input & ML).** 2D probability heatmap on (x_1, x_2) with decision boundary and point overlays.
- **Top-Right: Objective Space (Pareto & Feasible Context).** Two faceted 3D scatter views split by f_4: *Panel A*: $f_4 = 0$, *Panel B*: $f_4 = 1$.
- **Bottom-Left (Support): Parallel Coordinates and/or SPLOM.** Multi-dimensional trade-off reading and brushing across all four objectives.
- **Bottom-Right: Details & Inspector.** Exact values for hovered/selected points and pinned comparison table.
- **Right Sidebar: Controls & Filters.** Global view toggles, opacity sliders, range filters, and linking controls.

5 Panel Encodings & Interactions

5.1 Design Space Panel (2D Heatmap)

Visual encoding:

- Heatmap color $\to Z(x_1, x_2)$ (probability of class 1).
- Decision boundary $\to$ thick contour at $Z = 0.5$ (plus optional contours at $0.1, 0.9$).
- Feasible points $\to$ tiny, low-opacity dots.
- Pareto points $\to$ larger, saturated markers with outline/glow.
- Binary objective $f_4 \to$ marker *shape* (e.g., circle vs triangle) or stroke style.

Key interactions:

- Hover a point $\Rightarrow$ highlight same point in objective space and tradeoff views.
- Lasso/box select region $\Rightarrow$ create a working set linked to all views.
- Probe cursor on grid $\Rightarrow$ show $Z(x_1, x_2)$ and nearest point objectives (optional).
- Zoom/pan for local inspection.

5.2 Objective Space Panel (Faceted 3D)

Visual encoding:

- Axes: (f_1, f_2, f_3) in 3D.
- Feasible cloud $\to$ very faint points or density volumes.
- Pareto front $\to$ bold points on top (size + glow).
- Faceting by $f_4 \to$ two side-by-side panels for direct comparison.

Key interactions:

- Rotate/pan/zoom 3D.
- Hover a Pareto point $\Rightarrow$ ring highlight at its (x_1, x_2) in heatmap.
- Brush-select in 3D $\Rightarrow$ filters heatmap and tradeoff views.

5.3 Tradeoff View (Parallel Coordinates / SPLOM)

Purpose: reduce 3D occlusion and enable precise multi-criteria filtering.
Encoding:

- One axis per objective f_1, f_2, f_3, f_4 (binary shown as two categorical levels).
- Feasible set $\rightarrow$ thin, ghosted lines / density bands.
- Pareto set $\rightarrow$ thicker, saturated lines.

Interactions:

- Range brushing on any axis $\Rightarrow$ linked filtering everywhere.
- Axis reordering to reveal correlations.

5.4 Inspector Panel

- Shows (x_1, x_2), $Z(x_1, x_2)$, predicted class, and (f_1, f_2, f_3, f_4).
- **Pin/Compare:** users can pin multiple candidates and compare deltas.

5.5 Controls & Filters Sidebar

Core controls:

- Toggle: show/hide feasible cloud.
- Slider: feasible cloud opacity.
- Toggle: density vs sampled feasible points.
- Filters: objective range sliders and/or categorical f_4 filter.
- Toggle: split/combined view for f_4 (default split).
- **Toggle: show linking line**. When off, highlighting remains but lines are hidden.
- Toggle: show sampled points on heatmap.

6 Pareto Emphasis Rules (Always-On)

- Opacity separation: feasible $\alpha \approx 0.05$–0.15; Pareto $\alpha = 1$.
- Size separation: feasible 1–2 px; Pareto 6–8 px.
- Edge/glow: Pareto only.
- Draw order: Pareto always on top.
- Persistent legends clarifying feasible vs Pareto layers.

7 Scalability & Performance

- If Dataset A is massive, default to density rendering and progressive refinement.
- Pareto set is never sampled.
- Cross-view linking updates only the highlight layer for responsiveness.

8 Accessibility & Clarity

- Do not encode f_4 by color alone (use shape/stroke).
- Heatmap palette chosen for contrast and grayscale legibility.
- Axis direction (min/max) indicated with small arrows or labels.

9 Future Enhancements

- Knee-point detection and labeling in both spaces.
- Session save/load and export of views/selected solutions.
- What-if sliders for (x_1, x_2) with live ML and objective preview.
- Uncertainty visualization (ML confidence or Pareto robustness).