3 Results of the Lamps Dataset

Figure 5 show additional results with the lamps dataset. Also, we demonstrate a one-to-one shape abstract style transfer in Figure 6, where two different targets deformed to match a single source. Note that, the co-analysis with a larger dataset (in this example with all the models in Figure 11) is still necessary to generate the co-constrained abstractions and cluster the handles. However, once this stage is performed, one can utilize the optimization in Equation 6 of the main paper with a single source.

4 Semi-Supervised Gaussian Mixture Model for Comparison with the Constrained Mean-Shift

Let \( X = \{x_i\}, \) \( i = 1, \ldots, N \) be the observed surface feature vector from all the surfaces of all abstractions in category \( C. \) The traditional \( M \)-component GMM is:

\[
P(x|\Theta) = \sum_{k=1}^{M} \pi_k P(x|\theta_k) \tag{1}
\]

where \( \Theta = (\pi_1, \ldots, \pi_M, \theta_1, \ldots, \theta_M) \) are the parameters of the GMM \( P(x|\theta_k) = \mathcal{N}(\mu_k, \Sigma_k) \) is a normal distribution and \( \pi_i \) are the mixing coefficients.

If we let \( Y = \{y_i| i = 1, \ldots, N\}, y_i \in \{1, \ldots, M\} \) be the latent variables (cluster assignments of the observed data in the GMM), then the complete data-likelihood for the GMM becomes

\[
P(X, Y|\Theta) = P(X|Y, \Theta) P(Y|\Theta) \tag{2}
\]

where \( P(X|Y, \Theta) = \prod_{i=1}^{N} P(x_i|\theta_{y_i}), \) and \( P(Y|\Theta) = \prod_{i=1}^{N} \pi_{y_i}. \)

Following [Lu and Leen 2007] we can incorporate constraints into the model by introducing a weighting function \( g(Y) \)

Figure 2: Box and whiskers plot for the user study task completion times.
Figure 3: Left: Constraint propagation presented in the main paper. (a) Contact graph of handles. Surfaces into the page are omitted for viewing simplicity. (b) User edited handle in green, and system anchored handle in red. (c) System selected additional handles to be constrained in blue, for which the positions are computed by Equation 4 in the paper. (d) Resulting deformations. Right: Constraint aggregation resulting from another random pick of the initial handle node in subgraphs. (e-h) on the right corresponds to (a-d) on the left. Note the difference in the seat’s and pedal’s subgraphs and the resulting handle constraints (c & g).

\[
P(Y|\Theta, G) = \frac{1}{C} \left( \prod_{i=1}^{M} \pi_{y_i} \right) g(Y) \tag{3}
\]

\[
g(Y) = \prod_{i \neq j} e^{W_{ij} \delta(y_i, y_j)}
\]

Here \( C = \sum_Y \left( \prod_{j} \pi_{y_j} \right) g(Y) \) is a normalization term. Prior clustering constraints can be incorporated through the weights \( W_{ij} = W_{ji} \). \( W_{ij} > 0 \) indicates a soft link preference and \( W_{ij} < 0 \) indicates a soft do-not-link preference between \( x_i \) and \( x_j \).

**GMM clustering constraints.** For clustering we introduce soft link constraints between the surfaces in the seed surface clusters (as described in Section 4.1 of the main paper). Specifically, we set \( W_{ij} = K \) where \( K \) is a constant that controls the contribution of \( W \) in the GMM (\( K = 1 \) in our experiments). With these constraints, we can fit the GMM model with EM [Dempster et al. 1977] following the update rules of [Lu and Leen 2007].

**Comparison with constrained mean-shift.** As can be seen in Figure 6 of the main paper, this more compute intensive method has not shown significant accuracy gain in our experiments. However, with large datasets (\# of models > 10), Semi-supervised GMM has significant time disadvantages compared to the constrained mean-shift algorithm described in the main paper.

**Additional Remarks about Clustering.** Note that clustering is a process where success is highly dependent on the assumption that the data is well representative. For example, in the airplanes example, if the shape database that is used for learning mainly has two types of wings; one with straight, one that has noticeably high curvature curved wings then our system will cluster these two types into separate clusters and define constraints for both sets separately. However, note that in the real world most shapes exhibit a variety of different styles. If the shape database samples enough variety from the real world models, it will have the two end points (straight and high curvature curved wing), but also a variety of curved wings that slightly differ from each other starting from the straight one. In such a case, our algorithm will cluster all the wings into the same cluster, successfully revealing the variety.

5 Collections Used for Statistical Analysis and Handle Synthesis

Figures 7-11 show the datasets used to guide the results of this work. We will make these datasets public where there exists no licensing limitation.

6 Additional Remarks about the User Interface

**Moving or scaling entire segments.** Our prototype user interface offers a mode for moving or uniformly scaling an entire segment. The user simply turns the relevant mode on, and manipulators that appear on any handle of the segment will move or scale the segment uniformly depending on the mode activated.

**Silhouette sketching.** Silhouette sketching in our prototype UI enables the user to switch to an orthographic view and sketch the desired silhouette for the selected free-form handle. Once the user draws the desired silhouette, our system beautifies the user-sketched curve. Afterwards, the mesh vertices of the handle is moved such that their depth is kept constant but their positions in the 2D orthographic plane is fit to the sketched silhouette curve by first matching the end points.

**Violation notification.** We display the violations as a list based on their types (i.e., position violation, orientation violation, etc.) in our prototype UI, and if the user clicks on a violation in the list, it is visually displayed to the user by highlighting the involved handles.
Figure 4: (a) Initial model with handles. (b) User edit in green, automatically determined anchor in red. (c) User edit in green, anchor in red, system detected and propagated constraints in magenta. (d) Resulting model. (e) Further edits: free-form sketched top surface and rotated side surface in green, detected anchors in red. (f) Symmetry detected and rotation propagated to the anchor accordingly by the system. (g) User edit in green, anchor in red, system detected and propagated constraints in magenta. (h) Resulting model.
Figure 5: Example handles and deformations from the lamps dataset.

Figure 6: Red: Source, Green: Targets where the style of the source will be transferred. Bottom: Results. In this example, both targets are independently optimized to match the target’s style.
Figure 7: Cars dataset used for in the statistical analysis and handle synthesis of results presented in Figure 1 of the main paper.

Figure 8: Robots dataset used for in the statistical analysis and handle synthesis of results presented in Figure 19 of the main paper.
Figure 9: Airplanes dataset used for the statistical analysis and handle synthesis of results presented in Figure 19 of the main paper.

Figure 10: Bicycles dataset used for the statistical analysis and handle synthesis of results presented in Figure 19 of the main paper.
Figure 11: Lamps dataset used for in the statistical analysis and handle synthesis of results presented in Figure 5 of this supplemental document.

References
