Fast Hypothesis Filtering for Multi-Structure Geometric Model Fitting

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Motivation

- Performance of clustering based robust multi-model fitting algorithms depends on quality of hypotheses generated.
- Sampling based hypothesis generation leads to a significant proportion of irrelevant hypotheses.

Contributions

- We propose a novel fast and efficient two-stage hypothesis filtering technique that can improve performance of clustering based robust multi-model fitting algorithms.
- Our approach leverages the asymmetry in the distributions of points around the inlier/outlier boundary via the sample skewness computed in the residual space.
- The output is a set of promising hypotheses which aid multi-model fitting algorithms in improving accuracy as well as running time.

Illustrative example- Multiple line fitting

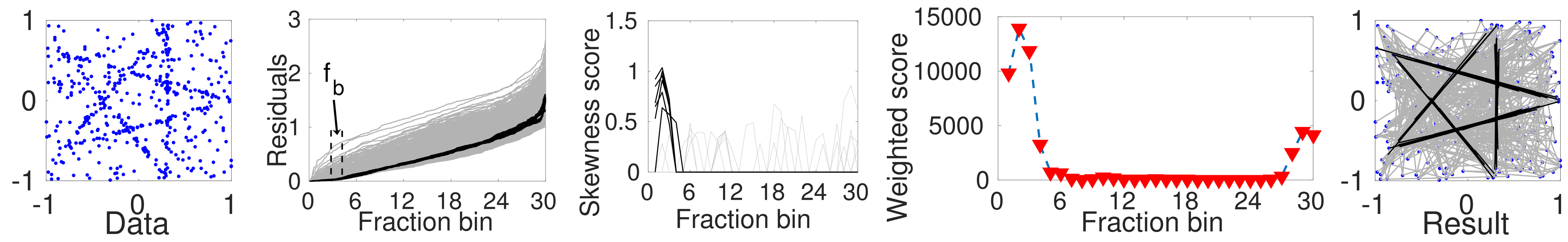


Figure 1: FHF pipeline: **Grey:**- Bad hypotheses, **Black:**- Good hypotheses

Results- Quantitative

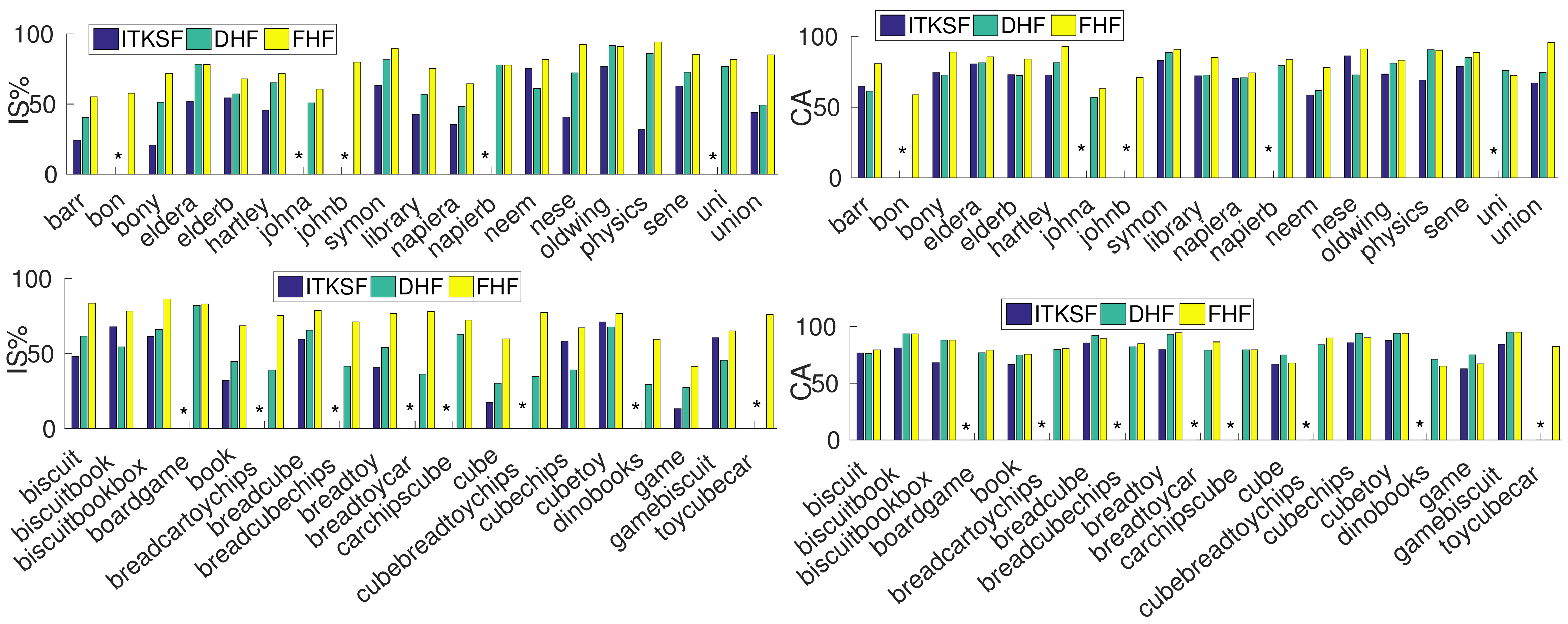
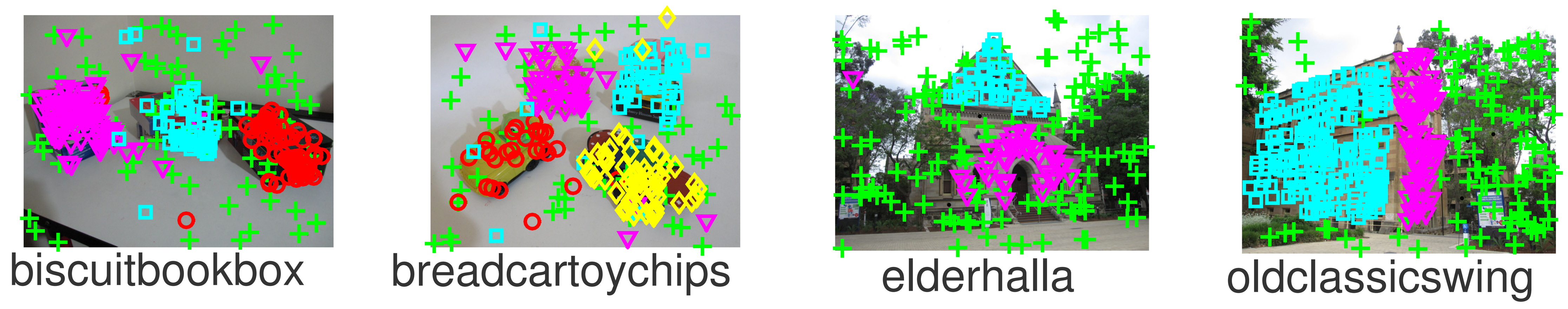


Figure 2: Comparison with ITKSF[1] and DHF[1]. **Row-1:** Homography fitting, **Row-2:** Fundamental matrix fitting. Clustering Accuracy(CA in %) of T-Linkage[3] when the input was the set of hypotheses retained by FHF. (AdelaideRMF[2] dataset).

Sample Results- Qualitative



(a) (b) (c) (d)

Figure 3: Fundamental matrix fitting(a,b), Homography fitting(c,d)

References

[1] H. S. Wong, T. T. Chin, J. Yu, D. Suter. A simultaneous sample-and-filter strategy for robust multi-structure model fitting In *CVIU'13*

[2] H. S. Wong, T. T .Chin, J. Yu, D. Suter. Dynamic and hierarchical multi-structure geometric model fitting In *ICCV'11*

[3] L. Magri, A. Fusiello. T-linkage: A continuous relaxation of j-linkage for multi-model fitting In *CVPR'14*

Proposed Approach

Data: $\mathcal{X}=\{x_j\}_{j=1}^{N}$
Initial hypotheses: $\vartheta = \{\theta_i\}_{i=1}^{M}$
Absolute residuals: $r_i^j = \phi(\theta_i, x_j)$

Stage-1 Skewness Based Filtering

- compute skewness score $\mathbf{S}_{iq}$ at each q^{th} *fraction bin*, $q = 1, \dots, Q$.
- $\mathbf{S}_{iq} = \frac{1}{\lceil wN \rceil} \sum_{j \in f_i^q} \left(\frac{\phi(\theta_i, x_j) - \mu}{\sigma} \right)^3$
- for each hypothesis retain only top three skewness scores $\overline{\mathbf{S}}$.
- skewness threshold $\tau = \min_q \max_i \overline{\mathbf{S}}_{iq}$
- $\mathcal{H}_q$ be the index set of hypotheses at the q^{th} fraction bin that yield a skewness value at least τ.
- weighted score $\mathbf{c}_q = |\mathcal{H}_q| \sum_{i \in \mathcal{H}_q} \overline{\mathbf{S}}_{iq}$
- largest fraction bin $\widehat{q} = \arg\max_q \mathbf{c}_q$
- $\vartheta_{\mathrm{I}} = \{\theta_i | \overline{\mathbf{S}}_{iq} \geq \tau,\ \theta_i \in \vartheta, q = 1, \dots, \widehat{q}\}$

Stage-2 Preference Based Pruning

- $\mathcal{X}^{\vartheta_{\mathrm{I}}} \subset \mathcal{X}$, comprising all minimal subsets corresponding to hypotheses in ϑ_{I}.
- $\mathcal{I}_k^{\theta_j^{\mathrm{I}}}$ be the index set of points in $\mathcal{X}^{\vartheta_{\mathrm{I}}}$ with the smallest k residuals with respect to $\theta_j^{\mathrm{I}} \in \vartheta_{\mathrm{I}}$.
- β is the overlap threshold.
- α is the minimum similar hypotheses.

Input:$\{\mathcal{I}, \vartheta_{\mathrm{I}}, k, \beta, \alpha\}$
Output:$\{\vartheta_{\mathrm{II}}\}$
begin
  for $j \leftarrow 1$ *to* $|\vartheta_{\mathrm{I}}|$ **do**
    $\vartheta_{temp} \leftarrow \{\emptyset\}$, $c \leftarrow 0$
    for $l \leftarrow 1$ *to* $|\vartheta_{\mathrm{I}}|; l \neq j$ **do**
      $olap = \left(\left| \mathcal{I}_k^{\theta_j^{\mathrm{I}}} \cap \mathcal{I}_k^{\theta_l^{\mathrm{I}}} \right| \right) / k$
      if $olap \geq \beta$ **then**
        $c \leftarrow c + 1$
        $\vartheta_{temp} \leftarrow \{\vartheta_{temp} \cup \theta_l^{\mathrm{I}}\}$
    if $c \geq \alpha$ **then**
      $\vartheta_{\mathrm{II}} \leftarrow \{\vartheta_{\mathrm{II}} \cup \vartheta_{temp} \cup \theta_j^{\mathrm{I}}\}$
      $\vartheta_{\mathrm{I}} \leftarrow \{\vartheta_{\mathrm{I}} \setminus \vartheta_{\mathrm{II}}\}$
return ϑ_{II}

Source Code

The source code is available at author's webpage

`https://www.iiitd.edu.in/~lokendert/`