Non-Rigid SfM
- 3D reconstruction of non-rigid objects from 2D temporal correspondences in a monocular image sequence.
- So far most approaches are batch.
- Our Goal: A sequential NRSfM method that is real-time capable.

Our Contribution
- A new shape basis based on modal analysis with bending and stretching modes. No learning step.
- An online solution to NRSfM that estimates camera pose and deformable shape on a per-frame basis.

Our Approach
- Stage 1: Computation of the shape basis. Only an estimation of the 3D shape at rest is needed.
- Stage 2: Bundle Adjustment over a sliding window to optimize deformation coefficients and rigid pose.
- Suitable to model a wide variety of deformations: from inextensible to highly extensible surfaces.

Stage 1: Physics-based Modal Shape Basis Computation
- Mode shapes are ordered by frequency spectrum, i.e. according to the energy needed to excite each mode:
  - Rigid modes (R): Rigid body motions.

Stage 2: Online Sliding Window Optimization
- Our energy includes image reprojection error terms for all visible points within a temporal sliding window of $W$ frames in addition to temporal smoothness prior. The optimization is solved using sparse Levenberg-Marquardt:
  $$\arg \min_{W_i} \sum_{i=f-W+1}^{W} \sum_{q \in M} \|W_{q} - R_{i} \left( S_{q} + (1 \otimes \Gamma_{f}^{T}) \Psi_{q} \right) \|^{2} + \lambda_{f} \sum_{i=f-W+1}^{W} \|q - q_{i-1}\|^{2} + \lambda_{r} \sum_{i=f-W+1}^{W} \|\Gamma_{i}^{T} - \Gamma_{f}^{T}\|^{2}$$
  - Non-rigid 3D displacement is approximated as a linear combination with $\Gamma$, weight coefficients.
  - Orthographic camera model:
    $$W_{f} = \begin{bmatrix} \frac{u_{1}}{v_{1}} & \cdots & \frac{u_{p}}{v_{p}} \end{bmatrix} = \Pi Q_{f}(S_{f} + T_{f})$$

Conclusions
- Real-time capable, accurate and scalable solution.
- Our method can handle both sparse and dense meshes and can cope with structured missing data.
- No additional inextensibility constraints.

Future Work
- Incorporate feature tracking and outlier detection to provide a unified framework.
- To exploit biomechanical priors.
- Application to Minimally Invasive Surgery.