

# Markerless inter-subject bone shape matching using 2D projections

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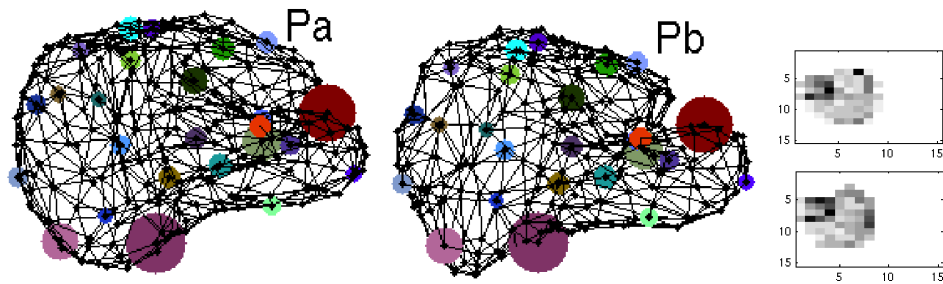
## 1 Introduction

Understanding and quantifying 3D bone-shape differences across groups of human subjects is important in the study of injury mechanisms and prevention, as well as for the design of orthopedic hardware. While statistical methods for analyzing 3D shape variation do exist, they generally require good correspondence between the different input shape samples. The challenge currently resides in establishing correspondence between inter-subject bone instances where corresponding features (*markers*) are difficult to identify without a high level of expertise. For example, articulation bones tend to be round and smooth, with rare clear salient features to aid the correspondence process.

We propose using bone 2D-projections and image correlation to automatically establish inter-subject bone shape correspondence. The intuition is that 2D projections are rich implicit shape descriptors that eliminate the need for extraction of salient features. We show this approach can successfully identify similarities between shapes and we present matching results on two inter-subject instances of a carpal bone.

## 2 Method

Bone surfaces are segmented from CT scans and modeled using NURBS surfaces such that instances have approximately the same number of vertices. Instances



**Fig. 1.** Two hamate bones from different subjects with a set of 25 point-correspondences automatically determined through our method. The size of the colored disks indicates how strong a match is. Right: the 2D-histograms generated from point Pa and point Pb are well correlated, indicating a match.

are then normalized with respect to scale and translated so that their centers of mass are aligned. We then create one 2D polar coordinates projection for each point on the surface of a bone instance, along the direction of the point normal to the surface. Projected points are binned based on their polar coordinates in a 2D histogram, with the bin size equal to twice the median edge length in each model. We establish potential point correspondences between different bone instances by selecting the pairs of 2D histograms that have a strong image-correlation index and were generated from points with similar space coordinates. For each surface point we retain the strongest matched point in the other instance. Only correspondences that define a bipartite match are kept. We finally filter out the weaker matches that are closer than twice the median edge length to stronger matches, generating thus a Poisson distribution of matched points on the surface of each model.

### 3 Results and Discussion

We present matching results on two inter-subject instances of a human wrist bone (Fig. 1). Each model has approximately 250 vertices. In this case, a bipartite set of 25 Poisson-distributed correspondences was generated in only a few minutes. The size of the colored disks indicates how strong a correspondence is. We note the correspondences are insensitive to the slightly different orientation of the bones during the scanning procedure.

Previous approaches to local surface matching have either focused on simple objects where features are easy to find, or required user interaction to select features [3]. Our approach is automated and particularly beneficial when identifying salient object features is nontrivial. We drew inspiration from work in computer vision [1,2], where similar 2D representations have been used in the context of same-object recognition and object-pose recovery. While in computer vision applications the focus is on selecting just a few strong correspondences that are also geometrically consistent with a rigid-body transform, we introduced new match-selection criteria that allow for non-rigid shape variation.

Potential applications of our technique range from automated transfer of areas of interest (such as ligament and tendon insertion point location, or cartilage-covered areas) from one bone instance to another, to quantitative analysis of bone surface measures such as location of contact area during motion, or curvature maps, across groups of human subjects.

### 4 Acknowledgements

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### 5 References

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