**Hacihaliloglu2014 - Local Phase Tensor Features for 3-D Ultrasound to Statistical Shape+Pose Spine Model Registration:**

* Starts with the importance of injection therapy for back pain, and the advantages US has over fluoroscopy and CT
* Difficulties in interpreting US images, hence the lack of widespread adoption
* Describes CT-US registration as dependent of CT segmentation and US image quality
* Mentions several point-based CT-US registration methods but describes them as being limited by dependence on US brightness/intensity, algorithm parameters and machine settings
* Introduces several local phase-based image processing methods as redressment to the intensity dependence of other pre-registration image processing methods
* Proposes the use of a gradient energy tensor (GET) filter to extract the local phase tensor (LPT) metric, and the use of this metric with a shape+pose model for improved statistical shape model registration
* Their method uses a band-pass (Log-Gabor) filtered image as input to the GET filter, requiring an exhaustive search for optimum filter center frequency, frequency bandwidth, and standard deviation parameters
* Landmarks manually chosen from SPs, and superior and inferior articular processes (not injection sites) were used for TRE-based assessment of their method
* Their method (GET/LPT) produced substantial quantitative (TRE) and qualitative (visualization) improvements in the subsequent registration compared to phase-symmetry and feature-symmetry filtering methods

**Rasoulian2015 - Ultrasound-guided spinal injections: a feasibility study of a guidance system:**

* Because of radiation, fluoroscopy should not be used as a guidance modality for spinal injections
* US based methods are proposed and undergoing research but are not yet adopted due to difficulty in interpretation
* Mentions CT based methods but says such scans are usually unavailable and result in radiation
* They use a statistical, mulit-vertebral model with separate shape and pose analysis of each vertebra for registration-based navigation visualization (see Rasoulian2013 for model and registration details)
* They constructed 3D volumes from tracked US scans using 3 scanning patterns to which they registered their statistical model, which was constructed from the CT scans of 32 patients
* Pose statistics were represented as similarity (rigid + scale) transforms which form a Lie group, which had to be projected into linear space with a logarithmic mapping
* Separate PCAs were performed on pose and shape modes of variability for the entire lumbar spine
* Before registration, US images were enhanced with the dynamic programming approach from Foroughi2007
* They validated the three stages of their method: US acquisition and registration accuracy were validated against prior CTs, where available, and guidance accuracy was validated by comparing needle position known from fluoroscopy to its position measured in the US mode

**Behnami2016 - Joint registration of ultrasound, CT and a shape+pose statistical model of the lumbar spine for guiding anesthesia:**

* Starts with the difficulty, prevalence, and risk of lumbar spine injections (facet joint and epidural)
* Lists fluoroscopy as standard of care
* Research done on ultrasound based visualization/navigation, but methods have not been adopted due to difficulty of interpreting ultrasound
* Methods which register CT segmentation to US are labor intensive for manual segmentation, and inaccurate for automatic segmentation
* Atlas registration errors “vary in magnitude and location”, therefore there is a need to improve and assess the accuracy of such models (their proposed method).
* Their method involves the joint registration of CT and US, edge detection in CT, phase-based bone probability measurement in US, and shape+pose statistical model registration
* Registration improvements mainly in SPs, and TrPs to some extent, when compared with atlas-US registration

**Koo2016 - Hierarchical CT to Ultrasound Registration of the Lumbar Spine: A Comparison with Other Registration Methods:**

* Deals with CT-US registration of spinal models for the sake of deformation assessment rather than visualization/navigation
* Proposes a “hierarchical” CT-US registration method and compares it with other methods in a dry-bone human phantom, and porcine cadaver
* Describes their intensity-based registration as an improvement on feature-based methods which rely on extracting bone surfaces from US, despite the fact that they locate voxels corresponding to bone in US with simple “backward ray tracing” threshold edge detection, assuming the brightest pixels correspond to bone
* Patient-specific models are constructed “semi-automatically” using a threshold, and each vertebra is rotated (presumably manually) to match the orientation in the US images
* The first step of their registration method is landmark-based for an initial guess. They use the SPs and TrPs of each vertebra for initial alignment.
* Voxels corresponding to the posterior bone surface in the CT are extracted using another raytracing method
* They state that two stepwise intensity-based registration steps are then used (although the distinction is not clear, both are apparently described in the same paragraphs and use the same objective functions). The objective function used for intensity-based registration finds transformations which maximize the mutual intensity between the posterior CT voxels, and their nearest neighbors (as per the “nearest-neighbor algorithm”) in the US dataset
* Vertebrae were each registered separately, and for speed, the US image sequences were manually under-sampled by inspection
* Four fiducial markers were attached to each vertebra to enable the computation of ground-truth, apparently created by registering a model to these landmarks, rather than locating and examining these corresponding landmarks on their proposed registration method’s results, or CT-ing their phantom/cadaver models
* Used inter-voxel distances to (incorrectly?) define their target registration error