4D DSA: New Methods and Applications for 3D Time-Resolved Angiography for C-arm CT Interventional Imaging

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Over the last decade, much advancement has been made in the field of interventional radiology and surgery. Advancements in interventional imaging technologies have led to improved imaging techniques for diagnosis, treatment planning, and treatment evaluation. These C-arm-based imaging systems now routinely feature high-resolution flat panel x-ray detectors and powerful x-ray tubes allowing for high-spatial resolution imaging. This new hardware technology has enabled such technologies as 2D fluoroscopy/roadmapping, 2D digital subtracted angiography (DSA), 3D DSA, and C-arm CT soft tissue 3D imaging that are now routinely used during many interventional cases. These technologies currently allow for time-resolved 2D projection imaging or static 3D volumetric imaging. However, they do not provide time-resolved 3D angiographic imaging, which may be of value to the clinician for pathologies that include complex vascular anatomy and blood flow patterns that are difficult to fully understand using 2D DSA and 3D imaging alone. 4D DSA is a new method that is based on undersampled reconstruction techniques previously used in the field of magnetic resonance angiography (MRA) to enable high-speed, high-quality time resolved 3D angiography.

4D DSA allows for the use of a single C-arm 3D DSA acquisition combined with an injection of contrast to derive time-resolved 3D DSA volumes that the clinician can view from any projection angle at any point in time. These volumes have isotropic spatial resolution of less than 0.5mm and in many cases can provide temporal resolution of the acquired projection data (typically on the order of 30 frames-per-second).

The work described in this dissertation is aimed at developing a basic validation framework for time-solved 3D DSA evaluation, developing metrics to characterize the complexity of vascular anatomy, optimize acquisition protocols for clinical practice, and evaluate initial pre-clinical and clinical results of the algorithm. These results are aimed at identifying methods, workflows, and potential clinical applications for 4D DSA. Finally, areas targeted for future research and development will be discussed in order to motivate continued work in this field.