Surface Rendering of Non-Cartesian 3D k-Space for Improved Visualization and Motion Detection

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Introduction:

Non-Cartesian 3D k-space sampling schemes [1-3] have recently gained popularity. Their advantages include shorter acquisition time, and reduced flow/motion sensitivity. Instead of acquiring planes in k-space, these trajectories acquire data on 3D surfaces. The cones trajectory [1] samples on a series of cones with varying heights and radii, while sharing a common vertex. Concentric cylindrical surfaces are obtained by 3D-interleaved cylindrical imaging [2]. Spherical navigator (SNAV) echoes [3] measures rigid body motion by sampling a spherical shell in k-space. Although traditional analysis tools usually plots raw data on a rectilinear grid, they are typically not well suited to display data on the sampling surfaces. The purpose of this work is to develop a method that can display the non-Cartesian 3D k-space on an appropriate surface by texture mapping and gridding. Combined with a registration process, rendering of the data can further benefit the motion detection for SNAV data.

Methods:

Algortithm: The surface rendering entails four steps. First, the 3D sampling *k*x, *k*y and *k*z coordinates of the raw data are calculated. Second, an evenly-spaced plotting grid is calculated for the targeted parametric geometric surface. Third, by using a gridding algorithm [4], which includes sampling density compensation and convolution with window kernel, the data are interpolated to the regularly spaced grid. Finally, the data matrix is projected to the targeted surface by texture mapping and image warping [5].

Method Validation by Cartesian data set: The technique was tested on a 3D Cartesian data set obtained from a numerical cylindrical phantom. Hybrid data was obtained with the inverse Fourier Transform the in the *kz*-direction. The k-space data to be projected onto a cylindrical shell surface with the radius equals to $5\times\Delta k$ was computed through the steps described above. Since the data are uniformly sampled, no density compensation is needed. The raw data are interpolated using the 3D-gridding algorithm described in [4]. The resultant data are then warped for mapping on the cylindrical surface.

Application to Non-Cartesian data set: In a second experiment, SNAV echo data acquired from a calibration phantom demonstrate the application of this technique to non-Cartesian data sets. The sampling scheme of this SNAV data is shown in Figure 1. For this specific example, the plotting grid matrix is established using a spherical coordinate system, where latitude and longitude determine the locations of surface features. The experiment was repeated by rotating the logical gradients by 10 degree about the secondary phase encoding direction to simulate the rotation of the phantom.

Results:

Figure 2 demonstrates the rendering effect of the 3D hybrid k-space data set on a cylindrical shell. Since the data have already been inverse transformed in z direction, the data are uniform along the z axis. The azimuthal dependence of the k-space data can be observed. Even though the object is circularly symmetric, the constraints of rectangular FOV causes angular dependence in k-space as expected.

Figure 3 is the display of the SNAV data. The rotation of the gradients caused the same amount of rotation of the k-space data, which is apparent when the two data sets are compared side by side. In this case, the rotation angle can be easily calculated by registering the longitude coordinates between the 2D texture maps.

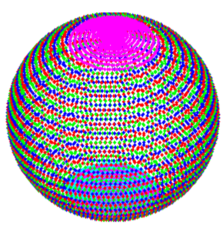

Fig. 1 The sampling scheme of this SNAV data, with different colors representing multiple interleaves of helical spirals. The polar ice cap parts are sampled by additional two spirals.

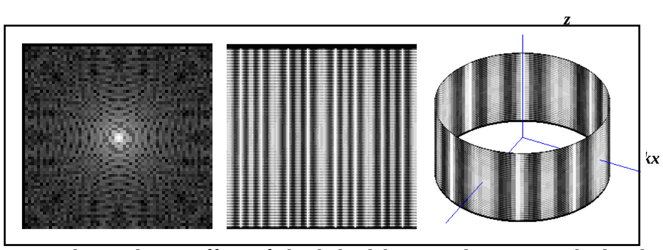

Fig. 2 The rendering effect of the hybrid k-space data on a cylindrical surface. The cross-section of the cylinder and the central slice of the hybrid data is shown in (a). (b) is the planar display of the data before it is texture mapped onto the cylindrical surface (c).

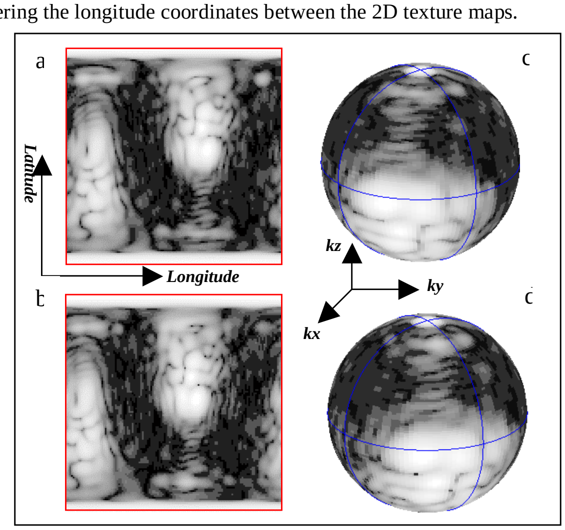

Fig. 3 The display of SNAV data on a latitude/longitude map and spherical shell surface before and after 10° rotation about the *kz* axis.

Discussion:

Traditional MR visualization software typically displays data on orthogonal planes. However, there are specific situations in which it is desirable to display data on other geometric surfaces. In this work, a technique enables visualization of MR raw data on non-planar surfaces has been developed. It was demonstrated by rendering on cylindrical and spherical surfaces. The algorithm can also be readily extended to any other parametric geometric surfaces. The method combined with registration process can also be applied to SNAV data to determine the amount of rotation.

References:

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