# Butterfly: A Self Navigating Cartesian Trajectory

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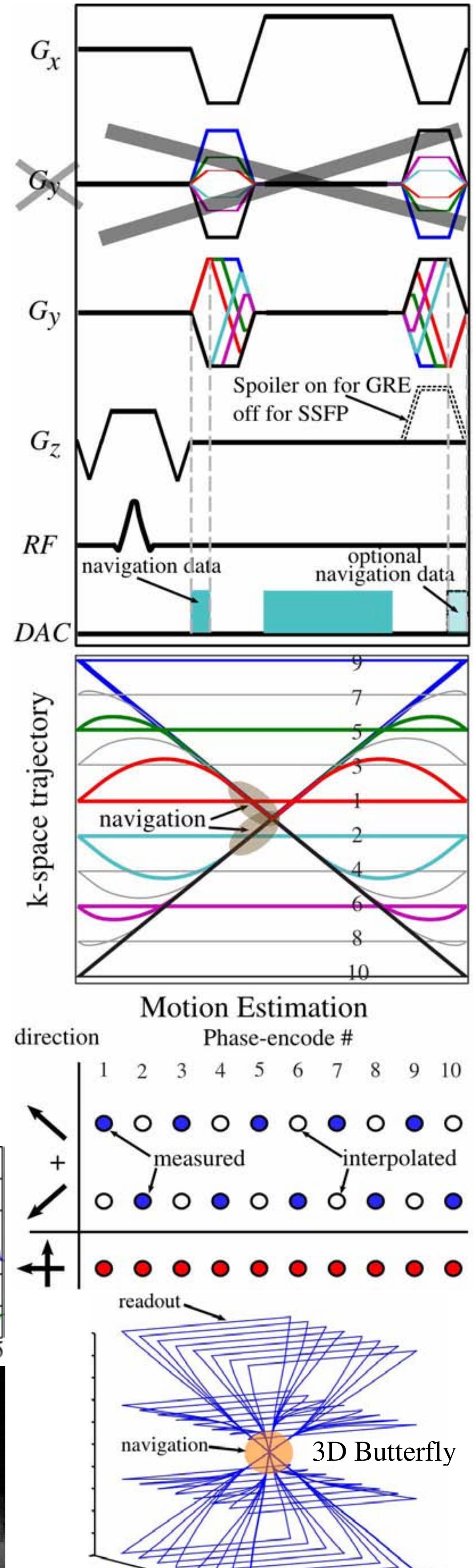
**Introduction:** Patient motion during scanning often causes image artifacts. Most motion artifact reduction techniques require additional scan time or complexity [1]. Others are able only detect the motion but not estimate it [1-2]. Inspired by the approaches of [1-3], a new self-navigating technique for Cartesian acquisitions is proposed. The method can detect and measure translational motion during the scan. The method has a negligible scan time-penalty, and the motion estimation and correction is fast and simple. It can be used as a replacement for current product pulse sequences, providing motion information and correction when needed.

***Figure 1: Top: The 2D Butterfly pulse sequence diagram and trajectory. Middle: the motion estimation procedure. Bottom: the 3D Butterfly trajectory***




**Theory:** Image translation due to motion causes a linear phase in k-space. The linear phase can be estimated by repeatedly acquiring the same k-space data – i.e, navigator echoes. By applying a simple modification to the spin-warp pulse sequence, the pre-winders and optionally the re-winders gradient waveforms can be used as navigators with negligible time-penalty. The phase-encodes gradient waveforms are modified to retrace a diagonal radial trajectory in k-space, which is used for navigation, as illustrated in Fig. 1. It is important that the slice refocusing and prewinders not overlap. The name Butterfly comes from the shape of the trajectory. A 3D variant of Butterfly is illustrated at the bottom of Fig. 1. For 3D, the slice encode gradient is modified as well.

**Methods:** Positive phase-encodes measure 1D translation in the top-left diagonal direction, negative phase encodes measure bottom-left diagonal one. To get a full 2D translation every TR, a centric k-space ordering is used and the motion measurements are interpolated (for 3D, the 4 quadrants of k-space are interleaved). Finally the phase of each readout is corrected.

To test our method, we scanned a knee of a volunteer using an SPGR sequence and the Butterfly trajectory (2DFT, TR=30ms, ReadOut=10ms, Nav-time=0.24ms, Flip=45, Res=300μm, Slice=2mm, NEX=4). The experiment was performed on a 1.5T GE Signa Excite scanner using a 3-inch surface coil attached to the knee. The volunteer was instructed to shake his knee during the scan. In plane motion was estimated and the data was corrected accordingly. The result was compared to a non-corrected reconstruction, and a scan without intentional motion.

**Results:** Figure 3 illustrates the results of the experiment. The rapid motion was estimated with sub-pixel accuracy over a large range of shifts. The corrected image exhibits similar high-resolution quality as the image acquired with no motion.

**Discussion and Conclusions:** By a simple modification free navigation information in Cartesian imaging is obtained every TR. This information can be used to correct for translation motion or as acception/rejection of data.

**References**: [1] Pipe JG Magn Reson Med. 1999 Nov;42(5):963-9 [2] Brau et. el, Magn Reson Med. 2006 ;55(2):263-70 [3] Crowe et. al, Magn Reson Med. 2004 ;52(4):782-8.

***Figure 2: (a) No-motion. (b) Uncorrected motion. (c) Corrected motion. (d) Motion estimate***