Technical Feasibility and Potential Applications of an optical Time-of-Flight camera mounted inside the MR scanner

Guido P. Kudielka[1,2], Anne Menini[1], Pierre-André Vuissoz[2,3], Jacques Felblinger[3,4], and Florian Wiesinger[1]
[1]*GE Global Research, Munich, BY, Germany,* [2]*Imagerie Adaptative Diagnostique et Interventionnelle, Université de Lorraine, Nancy, Lorraine, France,* [3]*U947, INSERM, Nancy, Lorraine, France,* [4]*CIC-IT 1433, INSERM, Nancy, Lorraine, France*

Audience: MR scientist or engineers interested in motion management and physiological sensors

Purpose: In MRI, pneumatic belt systems or navigators are used to measure breathing cycle for gating or observation purposes. Incorrect positioning of the belt/navigator or the non-physiological drift of the signal could lead to an unstable and unreliable respiratory signal resulting in degraded image quality. Various optical systems are used for motion tracking of the head[1] In addition to conventional 2D cameras, also 3D cameras (providing additional depth information) become available and getting explored for various applications; including position registration and diagnostics for healthcare purposes[2] Here we present the application of an in-bore 3D time-of-flight (TOF) camera to measure the respiratory cycle during an MRI acquisition as an alternative to pneumatic belts or navigators.

Method: A 3T HDxt MRI system (GE Healthcare, Waukesha, WI, USA) was equipped with a CamBoard pico, optical TOF camera (PMD Systems, Germany; cf. Table) at the iso-center of the magnet. The camera was controlled via USB with a Matlab script (Mathworks, MA, USA) on a standard laptop. Signal amplitude and distance information were recorded over the full FOV of the camera with a frame rate of 8 frames per second. A warm-up time of 10 minutes was allowed to avoid temperature drift. An abdominal volunteer measurement was performed using a 3D fast spoiled gradient echo sequence (FSPGR) (FOV=480×480×298mm^3, matrix=192×192×48, TR=4.8ms, TE=1.8ms, FA=15°) in free breathing and breath-hold examinations. For respiratory motion tracking a small ROI (10x10 pixel) was manually selected. Retrospective breathing motion correction was performed with the camera and belt data.

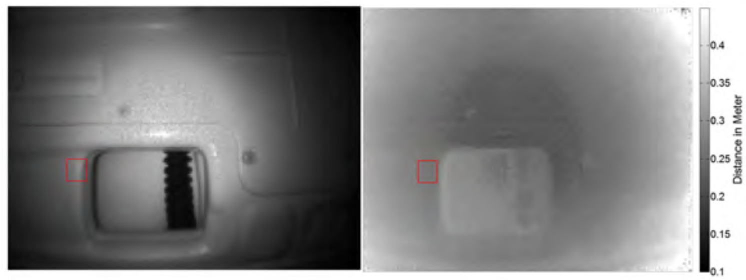

Figure 1: Intensity (left) and depth (right) image of the camera; The ROI used for respiratory motion tracking is indicated by a red box.

Results: The camera showed robustness against the main magnetic field, gradient fields and RF fields. The temperature of the camera increased significantly in the magnetic field, which might be related to a higher current consumption of the infrared-LED. An additional USB hub with an external current source and a guided air flow inside the magnet bore resolved these issues. The distance and amplitude signals show very good correlation (R^2=0.88 for intensity, R^2=0.86 for depth) when compared with the respiratory belt (Fig 2). Motion artifacts were successfully reduced with a retrospective gating reconstruction based on the camera information (Fig 3)

Resolution	160×120 px
Viewing angle	82°×66°
depth measurement range	0.2-1 m
depth resolution	<3mm (@0.5 m)
max. 3D frame rate	45 fps

Table: Technical specifications of the pmd Camboard pico TOF camera

Discussion: Overall, the 3D TOF camera demonstrated promising MR compatibility when tested inside a 3T MR environment. The significant initial temperature increase (~20°C) and associated drift of the signal could be handled by allowing a warm-up time of ~10min. Interferences originating from intensive RF pulsing can potentially be reduced and eliminated using standard RF shielding techniques. Due to the ability of measuring distances, TOF cameras give more information and an absolute quantification which can be of great value for advanced motion corrections.

Conclusion: In this work we investigated the technical feasibility of a 3D TOF camera operated inside a 3T MR scanner for contactless and marker-less respiratory motion tracking. Generally any optical observation inside the bore could be a possible application, especially if absolute distance data is of interest.

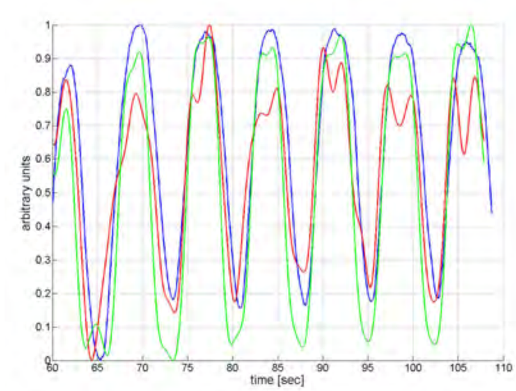

Figure 2: comparison of pneumatic belt data (blue), intensity (green) and distance (red) information from the TOF camera

References:

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2 Bauer, S., et.al. Real-Time Range Imaging in Health Care: A Survey. In Time-of-Flight and Depth Imaging. Sensors, Algorithms, and Applications. 2013:228-254). Springer Berlin Heidelberg.

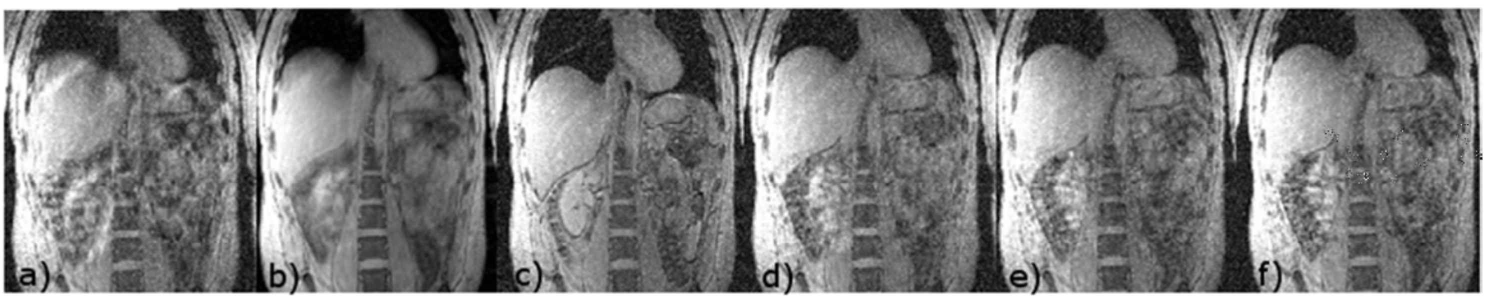

Figure 3: coronal images in a) free-breathing, b) 8 NEX average, c) breath-hold and retrospective gated images based on d) intensity , e) distance and f) pneumatic belt data. The retrospective gating results obtained using the TOF camera are indistinguishable to the ones obtained using the standard belt.