Improvements of respiratory motion recording: optical belt vs pneumatic belt

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INTRODUCTION:

Patient motions induce artifacts such as ghosting or blurring which can reduce MR image quality. To decrease the motion artifacts influence, several techniques have been used. One of the mostly used techniques in clinical examination is the synchronization with heart activity and respiratory motion which often necessitates patient cooperation [1]. An alternative to this technique consists in using a motion model based on prior knowledge provided by motion sensors [2]. The used (external or internal) motion sensors for this technique need to provide highly correlated information with internal organ motion. For respiratory motion, the most widely used sensor in clinical conditions is the pneumatic belt, which has the advantage of being non-magnetic and relatively inexpensive and which gives a well correlated signal with the position of the diaphragm [3]. However, they suffer from two main shortcomings: signal drifts and leaks. These drift corresponds to the high pass filter introduces either in the pneumatic part or in the electronic circuit to avoid saturation of system. Another explanation of this problem is the change in the position of belt on the patient during examination, mostly due to their shape.

During the European project OFSETH (*Optical Fiber Sensors Embedded into technical Textile for Healthcare*) [4], an optical external sensor has been developed. This optical sensor in form of belt offers the advantage of being free from metallic or electrical conductive parts and unperturbed by the electromagnetic environment changes. In addition, the signal obtained is an absolute measure and it has no voluntary drift. It has a linear sensitivity to longitudinal mechanical stresses. This sensor could be an alternative to the pneumatic belt.

MATERIALS AND METHODS:

The developed external sensor (*Fig. 1*) is based on an optical fiber Bragg grating sensor (FBG) [5] which is characterized by a good sensitivity. This component realizes a UV (Ultra Violet) interferometry pattern. It reflects the Bragg wavelength and transmits all other wavelengths. With this kind of filter, a strain applied to it either as an elongation or a compression, induces a shift of the Bragg wavelength. It is possible to measure this shift with a spectrometer using the wavelength of the reflected light. To evaluate the optical sensor, the first tests were performed on phantoms with a homemade mobile platform. This platform is composed of a removable part for the vertical translation motion and of a respirator that provides the inflation of an anesthesia balloon placed under the removable part. We also placed two pneumatic belts onto the platform to compare them with the proposed sensor (*Fig. 2*). The tests were carried out with the same parameters of sequences for phantoms and volunteers. Five SSFP sequences were realized with a change in magnitudes and frequencies of the respirator to simulate different human respiratory modes. With the purpose of extracting motion information directly from the image series, motion detection was performed with a Brox method [5] on every image series. The resulting respiratory signals were extracted from a region of interest (ROI) selected manually in a phantom.

Fig. 2: Tests on phantoms

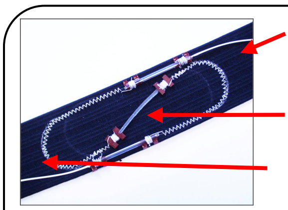

Fig. 1: FBG textile integration

For the second tests, a test protocol accepted by the ethics committee was implemented. It focused on comparing optical belt signals to respiratory signals obtained with classic pneumatic belts. Four healthy volunteers underwent a chest examination on a 1.5T or on a 3T MR scanner (S Signa HDxt, GE Healthcare, Milwaukee, WI). For each subject, several temporal series in a sagittal plane were acquired with an SSFP sequence, with 512x512 spatial resolution and 180ms temporal resolution. The series were acquired in different respiratory modes, including breath-hold to evaluate the stability of sensor, free breathing and deep breathing to assess sensor saturation. Two respiratory belts were used to monitor abdominal and thoracic respiration. These sensors were connected to a custom Maglife (Schiller Medical, France), a device dedicated to physiological monitoring in MRI. The novel sensor was placed under one of the two respiratory belts. All physiological signals were acquired and recorded using SAEC (Signal Analyzer and Event Controller), a real time signal processing unit comprising a dedicated computer and electronics system [6].

RESULTS:

A snapshot of results obtained on phantoms and on volunteers is presented in Fig. 3. It illustrates a comparison between the signal from optical belt (*Optical belt*) and signal from pneumatic bellow (*Pneumatic belt*). For phantoms the internal displacement signals extracted from the image series (*A-P motion*) is also compared with optical belt. These results are also quantitatively compared in terms of correlation coefficients given in **Error! Reference source not found.** For phantoms, the results are given by averaging five SSFP sequences. For each volunteers, an average of three different deep breathings and two breath holds was used.

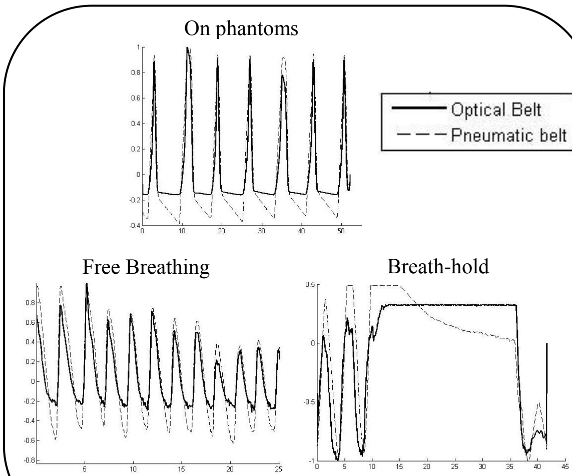

Fig. 3: Normalized signals of optical belt and pneumatic belt, on phantoms and on a volunteer

a) On phantoms

Optical Belt	
vs Pneumatic Belt	vs A-P motion
0.97 (0.02)	0.91 (0.06)

b) On Volunteers

	Optical Belt vs Pneumatic Belt		
	Deep breathing	Free Breathing	Breath hold
Subject 1	0.95 (0.02)	0.98	0.95 (0.03)
Subject 2	0.94 (0.02)	0.97	0.96 (0.02)
Subject 3	0.75 (0.18)	0.62	0.92 (0.08)
Subject 4	0.93 (0.03)	0.92	0.87 (0.10)

Table 1 : Absolute value of correlation coefficient between optical and pneumatic belts a) on phantoms and b) on volunteers

It can be shown from table results that the optical belt is well correlated to the results from pneumatic belts, which gives the same motion information. Moreover, it can be seen from *Fig. 3* that the optical belt has no drift during breath hold. For the subject number 3, a difference between the two belts appears. In its current form, the optical belt is not well suitable for volunteers who have a low waist because of the used fixation system. This issue will be solved in new releases of the optical bellow.

CONCLUSION:

This work demonstrates the feasibility of measuring respiratory motion with an optical belt based on an FBG sensor. The proposed sensor can correct the disadvantages of the pneumatic belt, particularly for breath-hold. In addition, the used of FBG sensors offers the possibility of measuring a local deformation in different points which could be used in reconstruction algorithm [7].

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