Title:
Bayesian motion estimation applied to cardiac ultrasound imaging

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Scientific domain:
%scientific_domain

Subject short description:

Background

The assessment of cardiac morphology and function in ultrasound imaging is an important research field with several crucial medical applications. The first and the most important step in detecting and characterizing cardiac diseases consists of estimating the motion of the heart during a cardiac cycle. Numerous motion estimation methods have been proposed in the literature and are mostly based on the optical flow approach or on the classical block matching method (initially proposed for video compression). However, several drawbacks have been reported,
such as the relatively bad spatial resolution of the estimated motion fields, motion artefacts or a high dependency of these methods on the motion model and on the choice of the hyperparameters employed.

In this thesis, we propose to formulate the motion estimation problem as an inverse problem that can be conveniently solved within a Bayesian framework. For similar problems in medical ultrasound imaging (tumour segmentation), efficient Markov chain Monte Carlo (MCMC) methods have been recently investigated in the IRIT laboratory (UMR 5505 of the CNRS). It has been shown that these methods are well adapted to the random nature of the ultrasound images and to the complex problems raised by the medical applications.

Theoretical studies

This research study aims at estimating the cardiac motion in ultrasound imaging, by exploiting the inverse problem formulation of this task. The inverse problem associated with the motion estimation problem is well-known to be ill-posed. We propose in this work to solve it using a Bayesian framework, which facilitates the consideration of complex priors on the motion field and the exploitation of the random nature of ultrasound images.

Tissue motion estimation in ultrasound imaging is an undergoing research topic. Numerous methods have been proposed in the literature, aiming at taking into account the two major problems raised by this topic: the complexity of the motion fields (high local deformations may appear) and the random nature of the US images. For the first issue, parametric motion models have been locally employed to model the deformation of the tissues (e.g., an affine transform has been proposed in [Suhling05] and B-spline functions in [Kybic03]). For the second issue, the fact that the ultrasound images are corrupted by a multiplicative noise (called speckle), makes obsolete the standard brightness constancy assumption. In order to overcome this limitation, recent works (including ours) propose to use the conservation of the spatial phase instead of traditional pixel brightness. The spatial phase is obtained using generalizations of the classical 1D analytical signal, such as multi-dimensional analytical signals [Alessandrini14] or monogenic signal [Alessandrini13].

More recently, a few papers proposed to use classical Bayesian frameworks to estimate the tissue motion in ultrasound imaging [McCormick11][Byram12]. However, the proposed priors for the dense motion fields are not adapted to the complexity of the cardiac motion. Moreover, the data attachment term is constructed from a classical cross-correlation function. The aim of this thesis is to propose more complex Bayesian approaches to estimate the cardiac motion, by taking into account adapted priors for the motion fields and for the hyperparameters classically used (such as the size of the local windows where the motion model is consistent). The data fidelity term will also be improved by taking into account similarity measures (such as the phase consistency) that are more appropriate to the nature of the ultrasound images.

Expected research goals

Objective 1:
The first objective of the thesis is to adapt some existing Bayesian frameworks to
the problem of cardiac motion estimation in ultrasound imaging. The results will be compared to state-of-the-art motion estimation methods using realistic simulation and in vivo images.

Objective 2:
The second objective of the study is to develop innovative algorithms of motion estimation, using a Bayesian framework based on priors and data attachments adapted to our application. The posterior distribution will be maximized using MCMC methods, adapted to high dimensional data.

Research schedule

The first stage of the Ph.D. will be devoted to an extensive study of Bayesian methods applied to motion estimation in medical imaging. The most promising ones will be further adapted to cardiac motion and to ultrasound imaging. In a second step of the work, the Ph.D. candidate will develop innovative motion estimation methods able to exploit the specificities of our application. The proposed algorithms will be compared to several state-of-the-art methods both on simulated images and on real data.

References related to Bayesian estimation


References related to motion estimation

[Suhling05] M. Sühling, M. Arigovindan, C. Jansen, P. Hunziker, and M. Unser,


**Two major publications in the domain of PhD:**


**Keywords:** Statistical signal processing, Bayesian inferences, Tissue motion estimation, Ultrasound imaging, Spatial phase

**Expected collaboration in China:**

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