Chapter 13

Predicting Complex Patterns of Human Movements Using Bayesian Online Learning in Medical Imaging Applications

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ABSTRACT

Medical images, in its tough sense, are fundamental in most clinical procedures and have become part of the medical act. Different acquisition methodologies result in a large variety of challenges or diagnostic tasks. Overall, most applications are dedicated to imaging structures so that complex measurements may be achieved. However, function analysis necessitates imaging structures through the time, either at the level of the image itself or at the interaction strategy between the user and the image. This chapter presents a Bayesian Framework which allows an adequate temporal follow up of very complex human movements, which somehow have been imaged. The Bayesian strategy is implemented through a particle filter, resulting in real time tracking of these complex patterns. Two different imaged patterns illustrate the potential of the procedure: a precise tracking a pathologist in a Virtual Microscopy context and a temporal follow up of gait patterns.

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INTRODUCTION

The movement, thought of as the change in the relative positions of the components of a system, reflects the very basic language of life, from cell or organic scales up to genetic ones. In complex organisms, movements may be classified in function of the degree of upper control as reflex and voluntary (Proc-hazka, Clarac, Loeb, Rothwell & Wolpaw, 2000). Reflexes can be understood as the response of living organisms to the necessity of transporting organic material within biological systems after some interaction with the external environment and with very little internal control, while voluntary means that there exists a kind of control for specific tasks such as search or locomotion and which is the result of large learning processes. Quantification of these movement results fundamental towards the comprehension of the structure and dynamics of every living system (Gavrila, 1999). Furthermore, many clinical or diagnostic decisions are based on measurements (Perry, 1992) whose accuracy depends on the proper tracking of anatomical structures. In our days one of the most powerful tools to study and quantify these movements in medical applications is the image analysis. The aim of this area is extracting useful information from the medical image at level of the signal or at level of the interaction between expert and image (Olabarriaga & Smeluders, 2001) and uses this information to increase the diagnostic efficiency. For the case of the movement the information of interest corresponds to patterns which must be capture the complexity of the underlying complex dynamic that generates the movement.

Overall the first approximation when tackling with complex dynamics is the use of linear models because of their mathematical simplicity e.g. superposition principle holds. However, in many Medical imaging applications, these linear models have poor performance: for example when non-additive noises are present, as the speckle ultrasound noise (Wagner, Smith, Sandrik & Lopez, 1983), or when there exist noises whose statistics are not Gaussians, as the quantum noise in an X-rays (Gardiner, 2000) or when the examined systems by themselves exhibit nonlinear dynamics, as for instance some complex gait patterns in neuromuscular disorders (Perry, 1992) or several elaborated medical gestures, i.e., the surgeon movements or an expert pathologist looking for information in a image (Doignon, Nageotte, Maurin & Krupa 2007; Gómez, Iregui & Romero, 2008). Recently, nonlinear and non-Gaussian models have been used as alternatives for modeling these complex problems in medical imaging, including image registration (Florin, Williams, Khamene & Paragios, 2005), video tracking (Smal, Draegestein, Galjart, Niessen & Meijering, 2008) or brain connectivity from neuro-imaging data (Stephan et al., 2008). Less known applications include image denoising, tracking of variables with clinical meaning and medical interactions (Zhai, Yeary, DeBrunner, Havliceck & Alkhouli, 2005; Gómez, Iregui & Romero, 2008).

The theory of Bayesian estimation formulates a general framework which allows calculation of model parameters and its state variables in nonlinear or non-Gaussian dynamics. Even though this theory has been available for decades, practical implementation is not been available because there are not analytical expressions but also computational resources are limited. In general, there is no a complete computational solution to this problem, except for simple models such as the linear Gaussian which admits a closed form: the Kalman filter. Consequently, most existing methods rely on simplifying assumptions to obtain tractable but approximated solutions. For example, Grid based approaches (Fox, Hightower, Liao, Schulz & Borriello, 2003) overcome the restrictions imposed by the Kalman filters using an approximation of the state space through piecewise constant representations. This approach can represent arbitrary distributions over the discrete state space. However, they are computationally complex, that is to say, inapplicable to highly dimensional state spaces.
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