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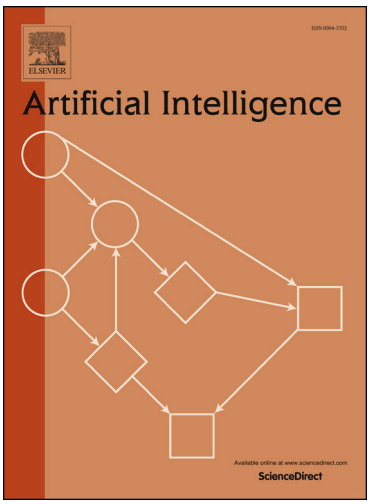

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Hierarchical semi-Markov conditional random fields for deep recursive sequential data

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Abstract

We present the *hierarchical semi-Markov conditional random field* (HSCRF), a generalisation of linear-chain conditional random fields to model deep nested Markov processes. It is parameterised as a conditional log-linear model and has polynomial time algorithms for learning and inference. We derive algorithms for partially-supervised learning and constrained inference. We develop numerical scaling procedures that handle the overflow problem. We show that when depth is two, the HSCRF can be reduced to the semi-Markov conditional random fields. Finally, we demonstrate the HSCRF on two applications: (i) recognising human activities of daily living (ADLs) from indoor surveillance cameras, and (ii) noun-phrase chunking. The HSCRF is capable of learning rich hierarchical models with reasonable accuracy in both fully and partially observed data cases.

Keywords: Deep nested sequential processes, Hierarchical semi-Markov conditional random field, Partial labelling, Constrained inference, Numerical scaling

1. Introduction

Modelling hierarchical depth in complex stochastic processes is important in many application domains. In a deep hierarchy, each level is an *abstraction* of lower level details [1, 2, 3, 4]. This paper studies *recursively sequential* processes, in that each level is a sequence and each node in a sequence can be decomposed further into a sub-sequence of finer grain [2].

Consider, for example, a frequent activity performed by human 'eat-breakfast'. It may include a series of more specific activities like 'enter-kitchen', 'go-to-cupboard', 'take-cereal', 'wash-dishes' and 'leave-kitchen'. Each specific activity can be decomposed into finer details. Similarly, in natural language processing (NLP) syntax trees are inherently hierarchical. In a partial parsing task known as noun-phrase (NP) chunking [5], there are three syntactic levels: the sentence, noun-phrases and